RADIOGRAPHIC ANATOMY OF THE HUMAN SKELETON

Skeleton from *On the Fabric of the Human Body* by Vesalius, published in 1543.

[*Frontispiece*

RADIOGRAPHIC ANATOMY OF THE HUMAN SKELETON

A HANDBOOK FOR RADIOGRAPHERS

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BALTIMORE
THE WILLIAMS AND WILKINS COMPANY
1961

Made and Printed in Great Britain.

FOREWORD

ALTHOUGH numerous textbooks on anatomy provide specifically for the needs of student radiographers, this further contribution on the osseous system jointly by Mrs W. H. Johnson and Dr J. A. Kennedy is most welcome. It is perhaps the first occasion on which pure anatomy and radiographic appearances have been so fully integrated for a complete system or so closely linked with practical positioning. In the training of radiographers, sound instruction in basic anatomy must be supplemented by adequate tuition in the appearance of the living subject as revealed by X-ray examination. It is this essentially radiographic aspect of the structures of the body which forms the background to the daily routine of the qualified radiographer, who must know on seeing the radiograph resulting from a given projection that the technique of positioning has been correctly applied: alternatively, to know whether important structures are misrepresented or missing, and thus to appreciate the correction necessary before embarking on the to be deplored repeat exposure. It is impossible to stress too highly the need for an early introduction to the radiographic appearances encountered in investigation of the various parts of the human body.

This book has been planned with these requirements in mind and presents a complete survey of the osseous system. The authors are admirably qualified for their task and the result of their collaboration is a book which is perfectly suited to the needs of the student undertaking a study of the human skeleton from the complementary viewpoints of pure anatomy, methods of radiographic investigation and radiographic appearances.

I have been much impressed with the concise form of presentation and with the obvious care which has been exercised in selecting and preparing the numerous illustrations, both radiographic and diagrammatic. I anticipate that this book will be warmly welcomed by teachers and students alike.

LONDON, 1961. K. C. CLARK.

PREFACE

THE authors have long felt that there is a need for a concise textbook of osteology for students of radiography, describing not only the principal anatomical features of the bones, but also demonstrating the main radiographic appearances in the normal subject. It is not intended that this book should be a comprehensive and detailed survey of the human skeleton, for which there are already many excellent large textbooks available, but should be of particular assistance to students of radiography in preparing for the examinations of Membership and Fellowship of the Society of Radiographers. It is strongly recommended that this book be read in conjunction with a practical study of the individual bones and the articulated skeleton. The order in which the bones are described differs from that found in most textbooks of anatomy, but we have thought it wise to conform to the order which most students follow in the classroom and in their practical work. An attempt has been made to bring the anatomical terminology up to date, but many older descriptive terms linger on, and these are given in brackets after the current term. Ossification of the individual bones has been described in greater detail than can be justified for examination purposes, and it is intended that these sections should serve mainly as a readily accessible exposition of this difficult subject. Although it is necessary in describing the radiographic appearances to indicate briefly how the radiographs were taken, detailed radiographic technique has not been given, since this subject is already adequately covered by existing textbooks.

We wish to express our sincere thanks to Ilford Limited who have provided all the prints from which the radiographic illustrations have been prepared. Many of these illustrations have been adapted from those published in *Positioning in Radiography* by K. C. Clark, M.B.E., Hon.F.S.R., and two are modified illustrations from *Oral Radiography* by W. H. Johnson. For permission to use these illustrations from the Ilford textbooks, we here make grateful acknowledgment. Our thanks are due to Mr L. C. Caswell, who has been responsible for the drawings executed with such care and attention to anatomical detail, and to Miss Ursula Evans, M.S.R., Queen Elizabeth Hospital for Children, Shadwell, who has provided the radiographs of children, from which most of the ossification series has been made. Thanks are also due to Mr A. S. Dilling, M.S.R., Miss E. Okell, F.S.R., and Mrs E. P. Fieldhouse, A.I.B.P. (Medical), of Ilford Limited for their assistance in preparing the illustrations, and to Mr D. Nightingale, M.S.R., St Helier Hospital, Carshalton, for his radiographic assistance.

We are greatly indebted to Professor T. Nicol, Department of Anatomy, King's College, University of London, for his constant interest throughout the period of preparation of this book: his comments and advice have been greatly appreciated.

W. H. JOHNSON.

LONDON, 1961. J. A. KENNEDY.

CONTENTS

A SHORT GLOSSARY OF DESCRIPTIVE TERMS

FOR purposes of description the human body is assumed to be in the erect posture with the arms by the sides and the head and the palms of the hands facing forward.

The following terms are in common use:—

MEDIAN PLANE . .	A vertical plane passing through the centre of the body and dividing it into a right and a left half.
SAGITTAL PLANE . .	Any plane which cuts the body parallel to the median plane.
CORONAL PLANE . .	A vertical plane passing through the body from side to side at right angles to the median plane.
TRANSVERSE PLANES .	Imaginary horizontal planes through the trunk at various levels. (*a*) Transpyloric plane—at the level of the first lumbar vertebra. (*b*) Subcostal plane—at the level of the lowest costal cartilages; this plane passes through the third lumbar vertebra.
MEDIAL (MESIAL) or LATERAL . . .	Terms denoting nearer to or farther from the median plane.
ANTERIOR (VENTRAL) or POSTERIOR (DORSAL) .	Terms denoting nearer to the front or the back of the body.
SUPERIOR AND INFERIOR.	Above and below.
INTERNAL AND EXTERNAL	Inside and outside.
PROXIMAL AND DISTAL .	Terms usually applied only in the case of the limbs and denote nearness to or distance from the trunk.

CHAPTER I

BONES AND JOINTS

FUNCTIONS AND STRUCTURE OF BONE

THE bones of the body form a framework or skeleton which supports the soft tissues and provides the necessary rigidity to the body as a whole. The skeleton supports the weight of the body and forms a number of levers which, when acted upon by the muscles, bring about body movements. It also forms the walls of cages or boxes which enclose and protect important structures such as the heart, the lungs and the brain. Bone consists essentially of a fibrous tissue meshwork impregnated with calcium salts, and so forms a store of calcium which can be released for body needs as required. It must be borne in mind that bone is a living structure; it is being constantly broken down and renewed throughout life and its external and internal form can change in response to altered stresses and strains. During the period of growth, up to the age of 16 to 18 years, bone growth and formation exceeds bone erosion; in adult life these two processes are balanced, whereas in old age bone erosion is in excess of bone formation.

If a long bone such as the humerus or femur is sectioned longitudinally, it will be seen that the shaft consists of a cylinder of compact bone surrounding a central or medullary cavity; the cavity contains yellow marrow composed largely of fat. At the ends of the bone the external layer of compact bone is thin and the interior of the bone is filled with a meshwork of spongy or cancellous bone containing red marrow, which is the chief source of the red blood corpuscles in adult life. The cancellous bone is arranged in a definite pattern determined by the stress and strain to which that particular part of the bone is subjected (Fig. 1). Where the end of the bone takes part in a movable joint, the thin layer of compact bone is coated with smooth articular cartilage to facilitate movement.

A section of compact bone, as seen under the microscope (Fig. 2), consists of units called Haversian systems. Each system comprises a central or Haversian canal surrounded by concentric rings known as lamellae which are composed of fibrous tissue impregnated with calcium salts. Small cavities (lacunae) lie between the lamellae and are interconnected by fine channels (canaliculi); the lacunae are occupied by bone cells. Blood-vessels and nerve fibres are present in the Haversian canals and nutrient fluids pass out from them through the canaliculi to all parts of the system. The spaces between adjacent Haversian systems are occupied by irregular lamellae known as

interstitial lamellae. The Haversian systems run roughly parallel to the surface of the bone and branch and communicate with each other. Compact and spongy bone differ only in the density of their microscopic construction.

The external surface of a bone, with the exception of the articular surfaces,

FIG. 1
Radiograph of the upper end of femur.

is covered with a thin membrane called the periosteum, which is closely adherent to the bone and to which the muscles and ligaments are attached. Blood-vessels pass from the periosteum into the bone substance, so that if the periosteum is stripped from the surface of a bone, the underlying bone may die due to loss of blood supply. Periosteum also has the power of bone formation and it is by this means that ossification takes place on the external

surface of a bone during the growing period; if the periosteum is damaged, bone cells may escape into the surrounding tissues and form irregular bone growths, a not uncommon feature seen on radiographs following fractures. Whilst compact and spongy bone are supplied with blood from the periosteum, bone marrow is supplied by vessels which enter the bone at the nutrient foramen and the position and direction of this foramen is constant for any one bone.

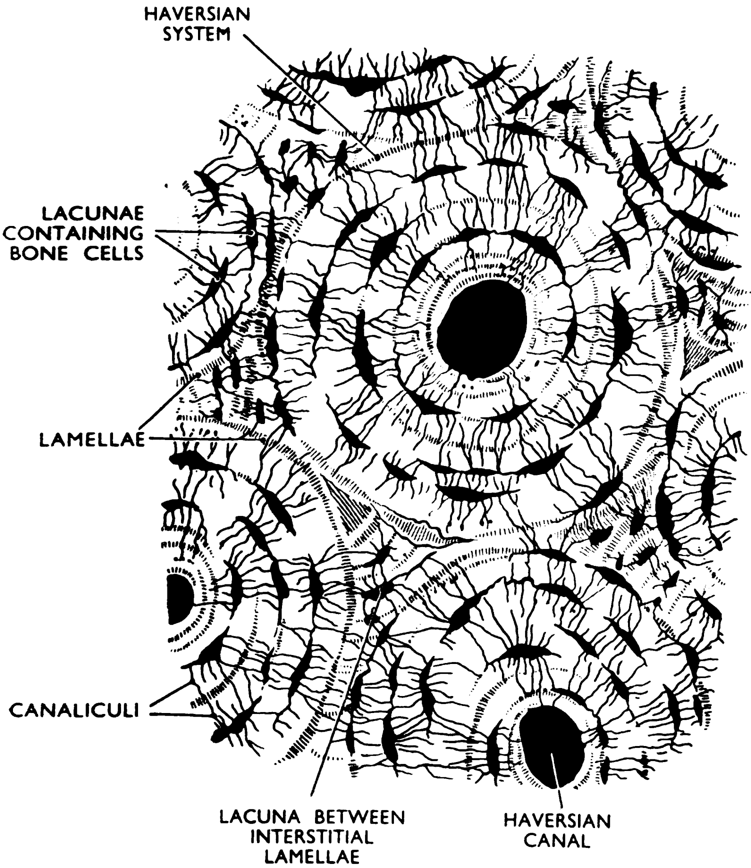


FIG. 2
Section of adult bone showing Haversian systems.

DEVELOPMENT OF BONE

Ossification of bone takes place in two ways—in membrane (intramembranous ossification) and in cartilage (intracartilaginous ossification)—and there is no basic difference between these two methods. The bones of the limbs, trunk and base of the skull are ossified in cartilage while bones ossified in membrane include those of the vault of the skull, the face and the clavicle. Ossification commences at one or more definite points in a bone known as centres of ossification, and these are constant for a particular bone.

Intramembranous Ossification

The bone is first modelled in membrane. At the site of ossification osteogenic fibres and bone cells appear; a gelatinous ground substance is formed between the fibres and in this calcium salts are deposited. During this process the bone cells become imprisoned in small spaces or lacunae in the ground substance or matrix. Ossification spreads out in all directions from the centre until the whole bone is ossified. At the same time the outer layers of the membranous model become the periosteum.

Intracartilaginous Ossification

This is best seen in a long bone, for example, the femur. In this case the bone is first modelled in membrane, but this is replaced early in foetal life by hyaline cartilage. Ossification commences near the centre of the shaft or diaphysis and consists of the gradual removal of cartilage and the simultaneous laying down of bone; this is carried out by bone cells called osteoclasts and osteoblasts. At the same time bone is also formed on the outside of the shaft by the deep layer of periosteum. These two processes spread until the shaft is completely ossified. In contrast, the ends of the bone remain cartilaginous until after birth, when secondary centres of ossification appear in them. The part of the bone formed from a secondary centre is known as an epiphysis and it is separated from the shaft by a thin plate of cartilage called the epiphyseal plate; this plate is important, as it is the site at which the bone grows in length. The bone increases in thickness by the new bone laid down by the periosteum. As the bone grows in length, the side of the epiphyseal plate nearest the shaft is invaded by spreading ossification but the side nearest the epiphysis continues to grow so that the thickness of the plate is maintained until the bone has attained its full length at about the eighteenth to twentieth year. In some way, due to hormonal influence, the epiphyseal plate now becomes replaced by bone and the shaft or diaphysis fuses with the end or epiphysis. The site of fusion is often visible in the radiograph of young adults as a line of denser bone and is called the epiphyseal scar. The name metaphysis is given to the part of the shaft adjoining the epiphyseal plate; as it is the area of the shaft where growth takes place, it is very well supplied with blood-vessels and blood-borne infection commonly commences here.

In each long bone there is one primary centre of ossification for the diaphysis and one or more secondary centres for each end. The primary centre appears during foetal life and the secondary centres after birth. In a radiograph of a newborn child (Fig. 3) it will be seen that ossification of the skeleton is well advanced. The time of appearance of the centres and of their fusion varies considerably from one person to another and the dates given for any bone are intended to represent an average figure. In general, it may be stated that the epiphyses formed from the secondary centres which appear

Fig. 3

first are the last to fuse with the shaft, so that one end of a long bone usually contributes more to growth in length than the other end. The nutrient foramina are directed away from the end of maximum growth, *e.g.*, in the upper limb they are directed toward the elbow since the epiphyses fuse earlier with the shafts in that region than at the shoulder or wrist. It is important to remember that fusion of some of the epiphyses with the shafts may be delayed or may never take place and these must not be mistaken for fractures. Accessory centres of ossification may also occur and can cause difficulty in the interpretation of radiographs; they are, however, usually present at the same site on the other side of the body.

CLASSIFICATION OF BONES

Bones are divided into four types according to their shape—long, short, flat and irregular.

Long Bones are found in the limbs and consist of a shaft and two ends. The shaft is a cylinder of compact bone with a central or medullary cavity. The ends of the bone are usually expanded and consist of spongy bone covered with a thin layer of compact bone; they provide a greater surface for articulation and muscle attachment.

Short Bones consist of spongy bone surrounded by a thin layer of compact bone. They are found at sites where strength but limited movement is required, *e.g.*, the carpal bones of the wrist and the tarsal bones of the foot.

Flat Bones include the bones of the vault of the skull and the shoulder blade (scapula) and are found where protection of underlying organs or space for muscle attachment is the principal need. They consist of two thin layers of compact bone enclosing a layer of spongy bone.

Irregular Bones are of varying shape; they include many of the bones of the skull and the bones of the vertebral column. They consist of spongy bone surrounded by a layer of compact bone.

The external surface of a bone commonly presents depressions and elevations. These features are produced in two main ways: the pull of the muscles and ligaments results in ridges and elevations, while depressions and grooves are formed by the pressure of overlying structures such as blood-vessels and nerves. Living bone is, however, constantly changing and adapting itself to varying stresses and strains, and can be moulded not only in early life but also by changing physical forces in adult life.

The following list gives the terms usually employed to describe the external features of a bone.

Elevations or Projections

Process—a projection.

Ala—a wing-like projection.

Condyle—a rounded elevation often covered with articular cartilage.

Crest—a narrow ridge.
Epicondyle—an elevation usually situated above a condyle.
Facet—a small smooth area often covered with articular cartilage.
Lamina—a thin plate.
Squama (squamous)—a thin flat scale.
Trochlea—a pulley-shaped surface, usually articular.
Tubercle—a small rounded elevation.
Tuberosity or trochanter—a large rounded elevation.

Holes or Depressions

Fissure—a narrow slit.
Foramen—a hole.
Fossa—a wide depression.
Meatus—a narrow passage.

JOINTS

The bones of the skeleton articulate with each other in various ways; some joints are immovable and others permit a wide range of movement. Three main types may be recognised: fibrous joints, cartilaginous joints and synovial joints.

Fibrous Joints

In fibrous joints the bones are joined together by fibrous tissue and no appreciable movement is possible. The joints between many of the bones of the skull (sutures) and the distal tibiofibular joint are examples.

Cartilaginous Joints

The opposing bone surfaces are connected by a plate of cartilage and bound together by ligaments; only a small degree of movement is possible. All joints of this type lie in the midline of the body and include the symphysis pubis and the joints between the bodies of the vertebrae.

Synovial Joints

The ends of the bones are covered with thin layers of articular cartilage and are separated by a joint cavity. The whole joint is surrounded by a fibrous capsule which is thickened in the lines of stress to form the ligaments of the joint. The capsule is lined with synovial membrane which does not extend on to the articular surfaces and which produces synovial fluid for the lubrication of the joint. There are many forms of synovial joints, *e.g.*, the elbow joint is a hinge joint and the hip joint a ball-and-socket joint. Some synovial joints contain a fibrocartilaginous disc or meniscus interposed between the articular surfaces; in the sterno-clavicular joint the disc divides the joint cavity into two separate compartments, but in the knee joint the menisci are present only on the margins of the articular surfaces of the tibia.

CHAPTER II

BONES OF THE UPPER LIMB

THE bones of the upper limb (Fig. 4) are those of the hand, the forearm and upper arm, with the intervening joints of the hand, wrist and elbow. The shoulder girdle consists of the scapula and clavicle, and suspends the upper limb from the trunk.

HAND

In the hand there are three groups of bones called the phalanges, the metacarpus and the carpus (Figs. 5 and 6).

Phalanges

There are three phalanges in each finger, named proximal, middle and distal. The thumb has only two phalanges—proximal and distal. Each phalanx consists of a proximal base and a distal head, connected by a narrow shaft which is flattened on its palmar aspect. The head of each distal phalanx is expanded to support the pulp of the fingertip. The heads of the middle and proximal phalanges are pulley-shaped, whilst the opposing bases of the distal and middle phalanges are ridged to conform to this configuration: only flexion and extension are possible at the interphalangeal joints. The bases of the proximal phalanges have oval concave articular surfaces to fit the rounded heads of the metacarpal bones at the metacarpo-phalangeal joints. This joint configuration allows for circumduction of the extended fingers in addition to flexion and extension.

Metacarpus

The five bones of the metacarpus are miniature long bones and together form the bony framework of the palm of the hand. From the lateral to the medial side they are numbered 1 to 5. They articulate with the proximal phalanges and with the distal row of carpal bones. In addition, the bases of metacarpals 2 to 5 articulate with each other.

The **first metacarpal bone** is shorter and thicker than the others, and the head is flatter. Its base forms a saddle joint with the trapezium of the carpus, sitting astride like a man on horseback. This particular form of joint brings the thumb into an oblique position in relation to the rest of the hand, enabling it to pass diagonally across the palm to the fingertips, so increasing the grasping power of the hand. On the flexor aspect of the first metacarpo-phalangeal joint two sesamoid bones are always present. A sesamoid bone is a nodule of bone

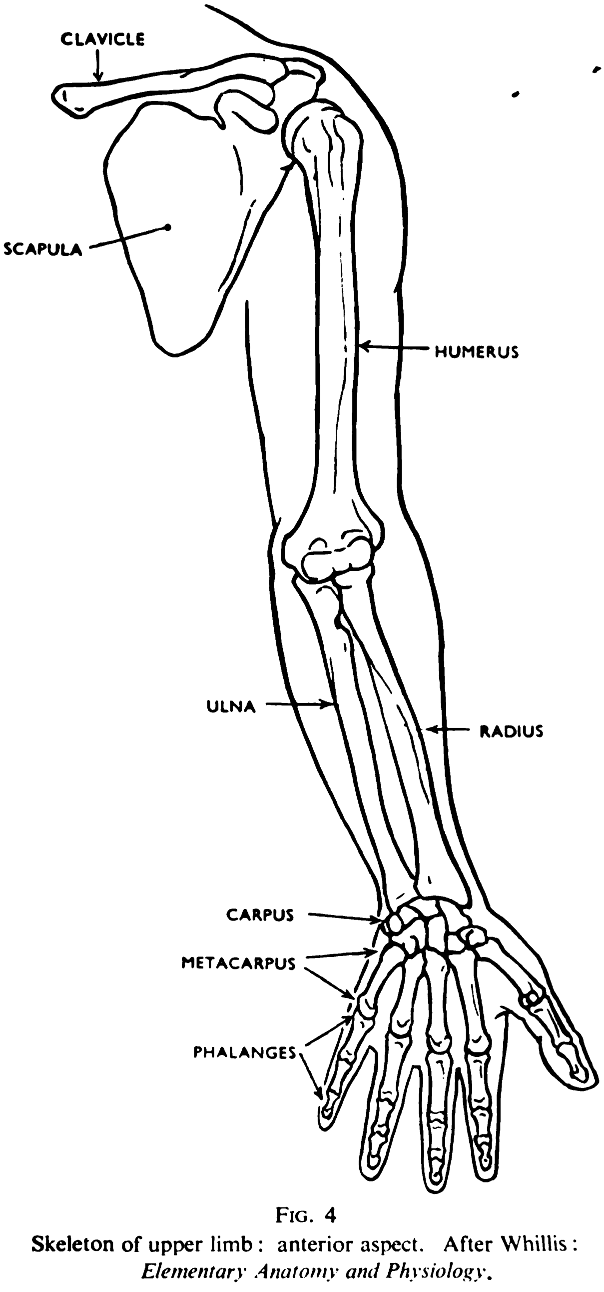


FIG. 4
Skeleton of upper limb: anterior aspect. After Whillis: *Elementary Anatomy and Physiology*.

found within the tendon of a muscle, usually near a joint; they protect muscle tendons from wear as they glide over bony surfaces. Sesamoid bones are

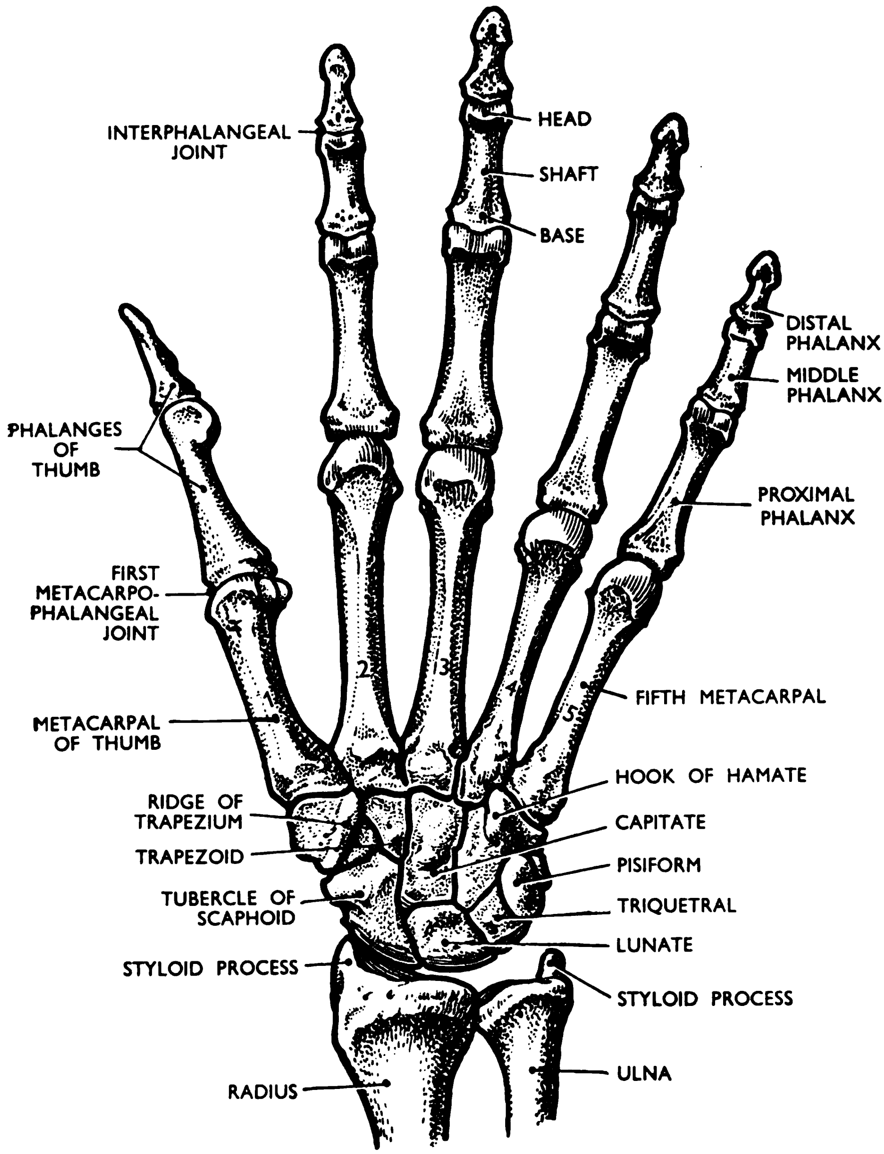


FIG. 5
The bones of the hand: palmar aspect.

found only on the anterior aspect of the hand; they may be found occasionally near the heads of the second and fifth metacarpals (Fig. 8).

The **second metacarpal bone** is the largest, and, like the remaining

metacarpals, it has a rounded head which overhangs the anterior or palmar aspect of the shaft. Its base articulates with three carpal bones—the trapezium, trapezoid and capitate.

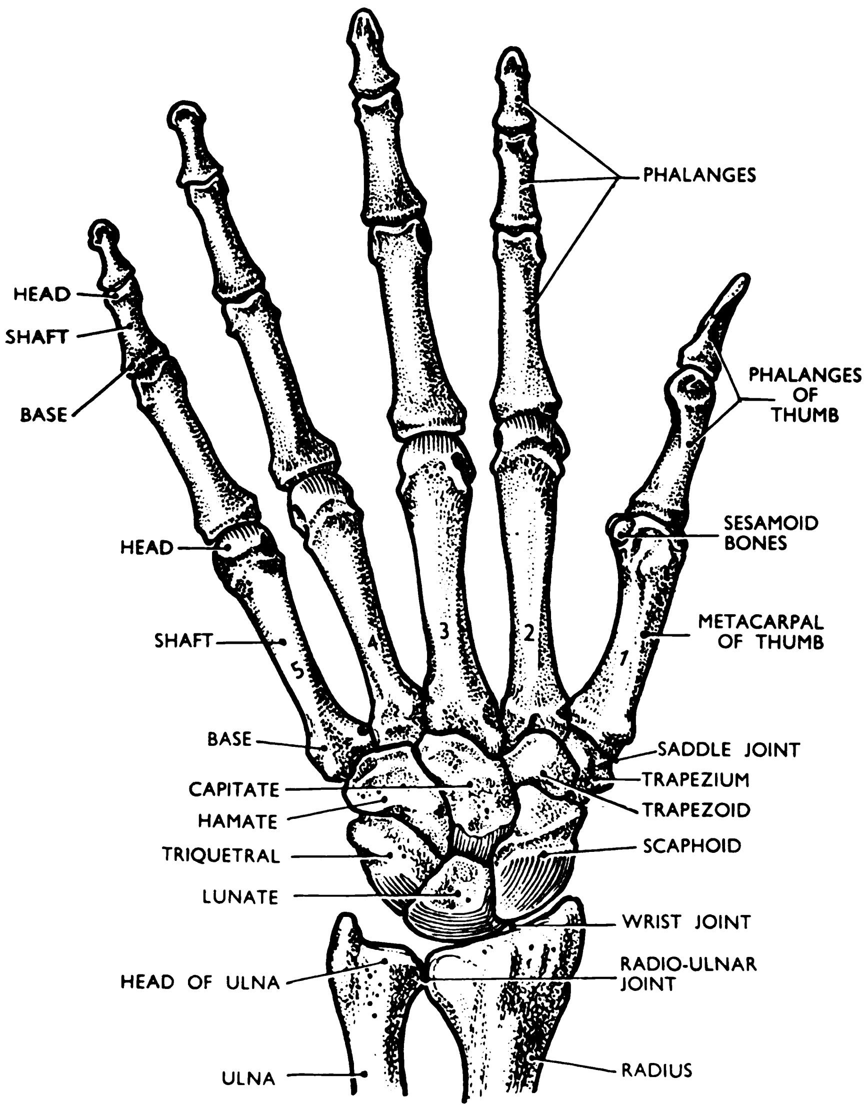


FIG. 6
The bones of the hand: dorsal aspect.

The **third metacarpal bone** can be distinguished by a small projection on the dorsal surface of its base—the styloid process. It articulates with the capitate bone of the carpus.

The **fourth and fifth metacarpal bones** are similar in shape to the others, but smaller; both articulate with the hamate bone of the carpus.

Carpus

The carpus consists of eight small irregularly shaped short bones arranged in two rows, each row consisting of four bones.

The names of these carpal bones (with alternative names in brackets) are:—

	Distal Row				
	Trapezium (Greater Multangular)	Trapezoid (Lesser Multangular)	Capitate (Os (Magnum)	Hamate (Unciform)	
Lateral side					**Medial side**
	Proximal Row				
	Scaphoid (Navicular)	Lunate (Semilunar)	Triquetral (Cuneiform)	Pisiform	

The bones of the distal row articulate with the bases of the metacarpals: those of the proximal row (with the exception of the pisiform) articulate at the wrist joint with the radius and the articular disc on the lower end of the ulna.

The two rows articulate with each other to form the midcarpal joint. The pisiform is really a sesamoid bone and articulates only with the triquetral.

The whole carpus forms an arch, concave on its anterior (palmar) aspect. This concavity is accentuated by the presence of four bony prominences, projecting forward from individual carpal bones. The two prominences on the lateral side are the crest of the trapezium and the tubercle of the scaphoid: those on the medial side are the hook of the hamate and the pisiform, which is situated on the anterior aspect of the triquetral. A ligament (the flexor retinaculum) converts the concavity into a tunnel through which nerves, blood-vessels and muscle tendons pass into the palm.

The scaphoid is the most important carpal bone to radiographers, since it is frequently fractured. It consists of two ends, the proximal and distal poles, separated by a waist. A small projection on the anterior margin of the distal pole is known as the tubercle.

RADIOGRAPHIC APPEARANCES OF THE HAND

Hand: Postero-anterior Radiograph (Fig. 7)

For this view, the hand is placed palm downward on the film, with the fingers extended and slightly separated.

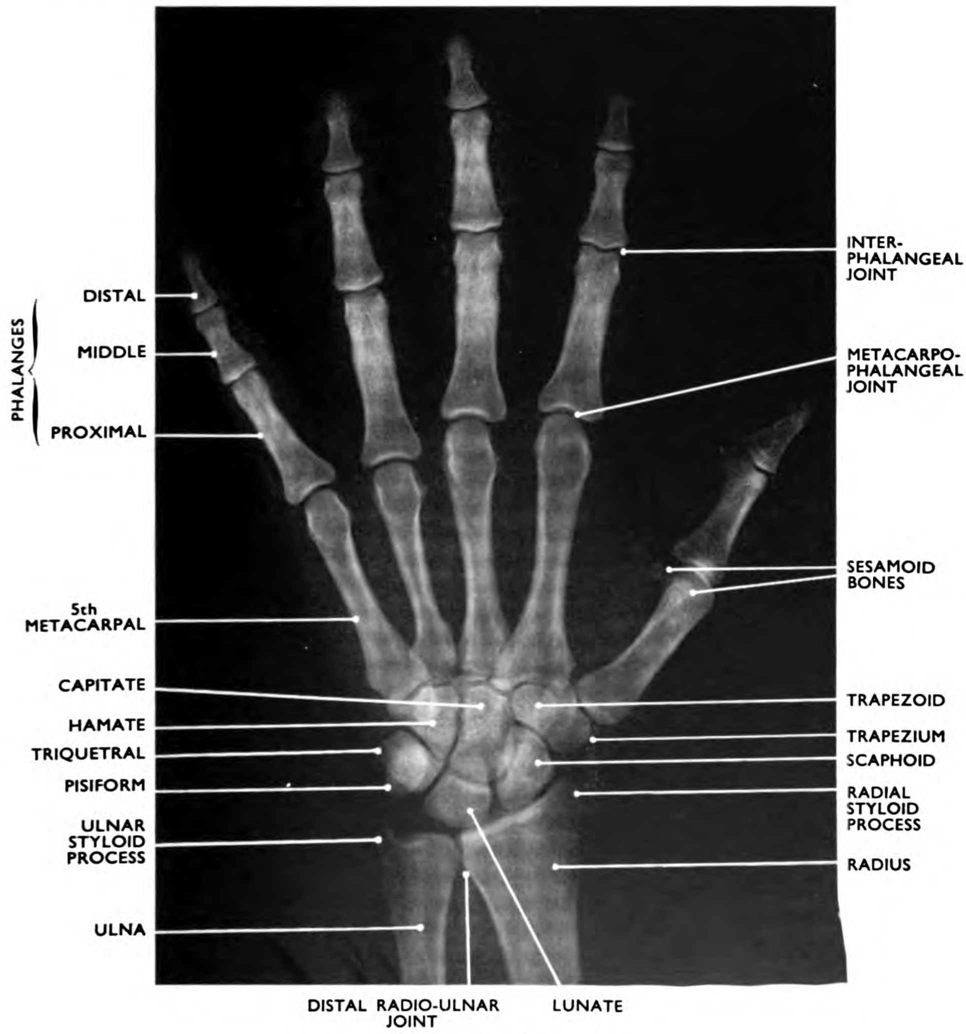


FIG. 7
Left hand: postero-anterior radiograph.

The resultant radiograph shows the main anatomical features of the metacarpals and phalanges. It will be noted that the thumb is in an oblique position in this view. Compare the length of the bones in the three rows and the shapes of the joint surfaces. The sesamoid bones of the thumb are plainly visible, one clear and the other overshadowed by the metacarpal head.

Hand : Lateral Radiograph (Fig. 8)

When radiographs are to be made of any area it is usual to take two views, with a variation of 90° between the two projections, as one alone can be very misleading. When, however, the hand as a whole is turned into the lateral position, the bones are projected one upon another in the radiograph, and

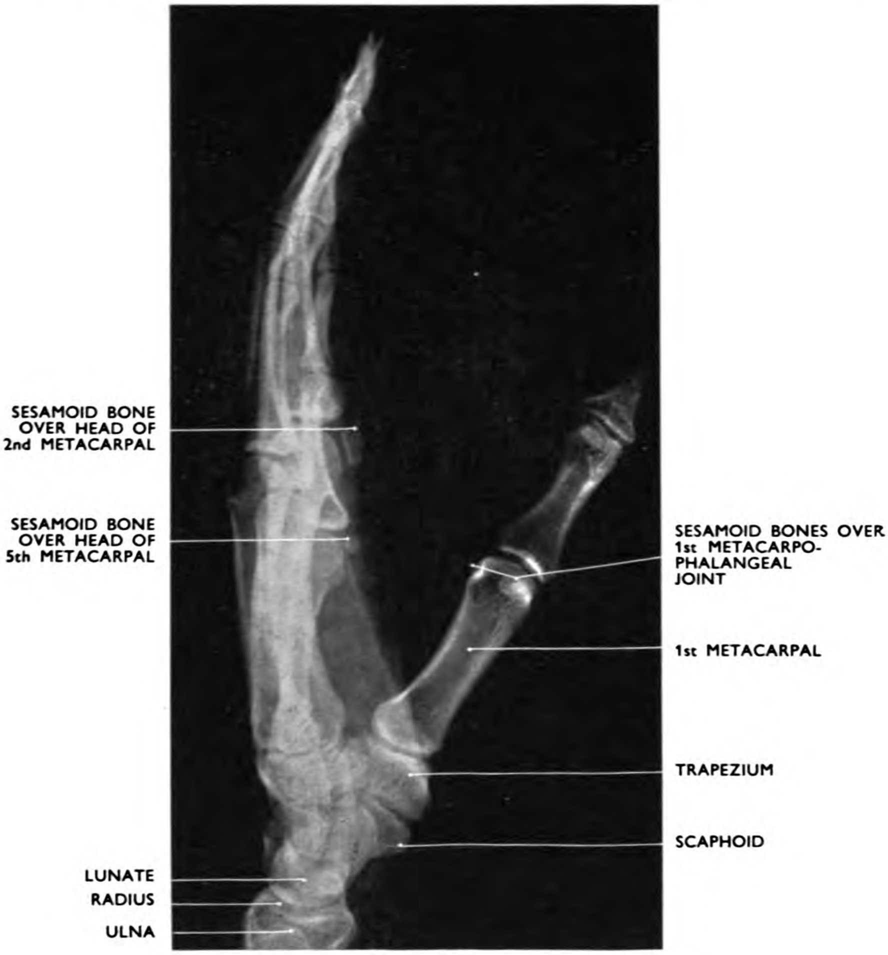


FIG. 8
Left hand : lateral radiograph.

indications of minor injuries may be lost in the confusion of shadows. Lateral views of individual phalanges can be obtained by simply extending the finger concerned clear of its neighbours, but this is not possible with the metacarpals. This difficulty may, however, be overcome by the use of the oblique projection. The lateral view is usually reserved for the location of foreign bodies in the palm. When the lateral projection is used for this purpose, the palm of the

hand is placed at right angles to the film, and the thumb, now uppermost, is drawn forward to separate its shadow from that of the palm. The lateral radiograph demonstrates clearly the slight concavity of the hand on the palm side; it also demonstrates the sesamoid bones.

Hand: Oblique Radiograph (Fig. 9)

For this radiograph the palm of the hand is at 45° to the film and the fingers are slightly flexed: the little finger is in contact with the film and the

FIG. 9
Left hand: oblique radiograph.

hand is cupped over a pad to support the thumb. On the radiograph it will be seen that the slightly flexed fingers are foreshortened and the metacarpal bones separated. The slight palmar overhang of the metacarpal heads should also be noted as this proves that a different projection of these bones has been achieved from that produced in the postero-anterior radiograph (Fig. 7).

Thumb : Lateral and Antero-posterior Radiographs (Figs. 10 and 11)

In radiographic examinations of the thumb it is important to include the joint between the first metacarpal and the trapezium of the carpus, as a Bennet fracture is a common occurrence at the base of the metacarpal.

FIG. 10 Lateral radiograph.

FIG. 11 Antero-posterior radiograph.

Left thumb.

For the lateral radiograph (Fig. 10) the thumb is tilted into position by slightly raising the palm of the hand on a pad.

For the antero-posterior radiograph (Fig. 11) the hand is rotated outward until the posterior surface of the thumb is in contact with the film.

Both radiographs show the sesamoid bones, and the saddle joint between the base of the metacarpal and the trapezium is clearly demonstrated.

Wrist Joint : Postero-anterior Radiograph (Fig. 12)

This view is taken with the palm facing downward on the film. The proximal one-third of the metacarpal shafts and the lower ends of the radius and ulna are included in the radiograph.

On the medial margin of the **distal carpal row** is the triangular-shaped hamate bone; the hook projects forward to produce a dense oval shadow. The centrally placed capitate is the largest carpal bone, whilst on its lateral side are the small trapezoid and trapezium, partly overlapping each other in this view.

On the medial margin of the **proximal carpal row** the oblong triquetral can clearly be distinguished, with the oval shadow of the pisiform superimposed

FIG. 12
Left wrist joint: postero-anterior radiograph.

upon it. The lunate partly overlaps the head of the capitate, and on its lateral aspect is the scaphoid. The tubercle of the scaphoid is visible as a denser curved line of bone near its distal pole. It is important to realise that in this postero-anterior radiograph the long axis of the scaphoid is inclined slightly downward (*i.e.*, in an anterior direction) and therefore a foreshortened view of this bone is seen.

The prominent styloid process on the lateral margin of the lower end of the radius and the corresponding ulnar styloid process are clearly visible. These two bony protuberances can be palpated easily and mark the line of the wrist joint.

The curved line of the proximal carpal row of bones fits into a concavity formed by the lower end of the radius; the concavity is continued over the lower end of the ulna by a disc of cartilage. This articular disc is not dense enough to cast a shadow, but occupies the transradiant space between the lower end of the ulna and the triquetral and lunate bones. The inferior radio-ulnar joint is seen between the lower ends of the two long bones.

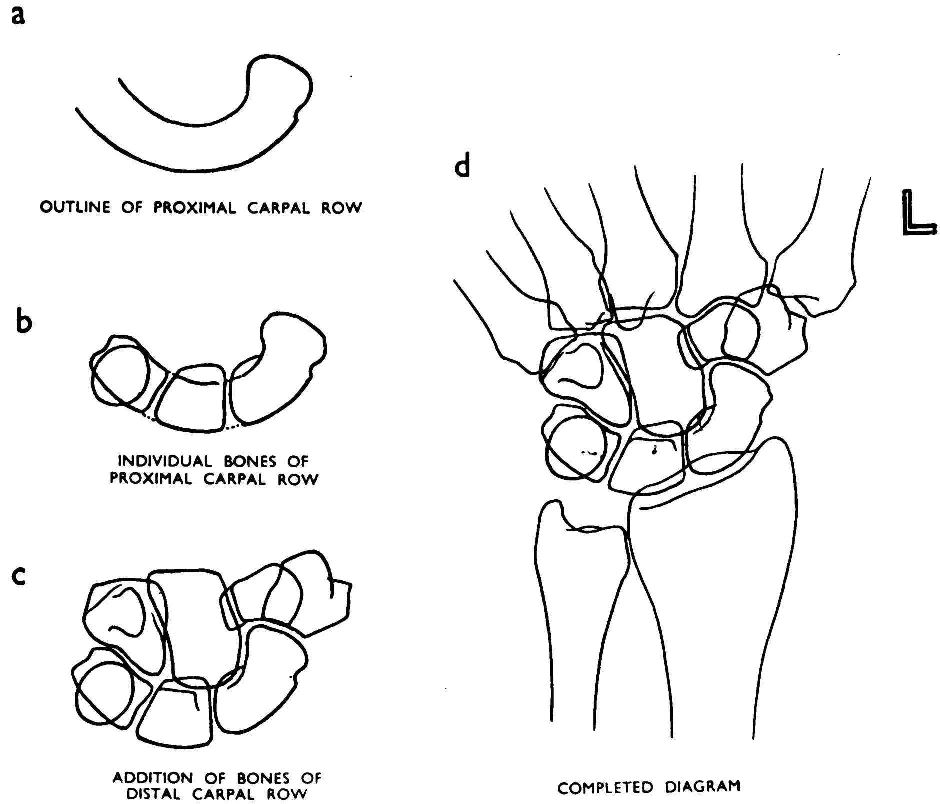


FIG. 13

A method of constructing a diagram of carpus (left wrist joint: postero-anterior view).

The shape of the wrist joint allows a wide range of movement, including flexion, extension, adduction, abduction and circumduction. Rotation at the wrist joint does not take place; this movement is effected by rotation of the bones of the forearm.

A simple method of constructing a diagram of this radiograph is given in Figure 13.

Wrist Joint: Lateral Radiograph (Fig. 14)

The lateral radiograph is taken with the palm of the hand tilted slightly backward from the lateral position.

FIG. 14
Left wrist joint: lateral radiograph.

Superimposition of a number of small bones in this projection makes it difficult to analyse the radiograph, but this can be achieved by a diagrammatic build-up of the left wrist joint, as demonstrated in Figure 15, adding first one bone and then another.

In Figure 15, A note the relative levels of the radial and ulnar styloid processes and the slightly concave radial articular surface.

In Figure 15, B the characteristic semilunar shape of the lunate can be seen. The rounded head of the capitate fits into its concave upper surface, and the convex lower surface articulates in the concave surface of the lower end of the radius.

In Figure 15, C the anterior inclination of the scaphoid is well demonstrated, and the tubercle on the anterior aspect of the distal pole is a prominent feature.

In Figure 15, D the rounded pisiform rests on the anterior surface of the triquetral.

Above the scaphoid in Figure 15, E is the trapezium with its prominent ridge forward. The trapezoid partially overlaps both the trapezium and the capitate.

Lastly, in Figure 15, F the hamate is largely overshadowed by the capitate; the hook, now in profile, projects toward the front.

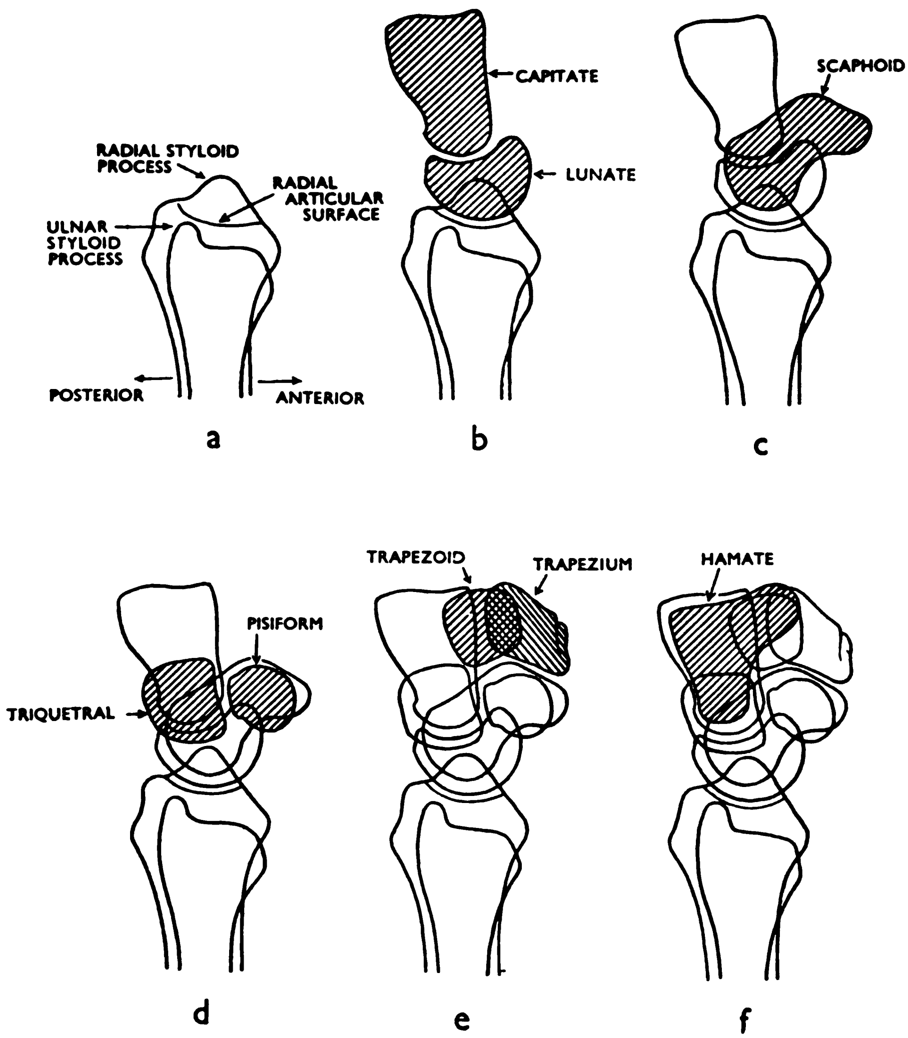


FIG. 15
A method of constructing a diagram of the lateral radiograph of the left wrist.

Wrist Joint: Oblique Radiographs (Figs. 16 and 17)

Oblique radiographs of the wrist joint are very important to investigate possible injury to the scaphoid—in fact, it cannot be said that an examination is complete without their use. Injuries to the triquetral and pisiform, although less common, may also only be seen on the oblique views.

In the posterior oblique radiograph (Fig. 16), the hand is facing downward and inward at 45°. Such a position brings the long axis of the scaphoid

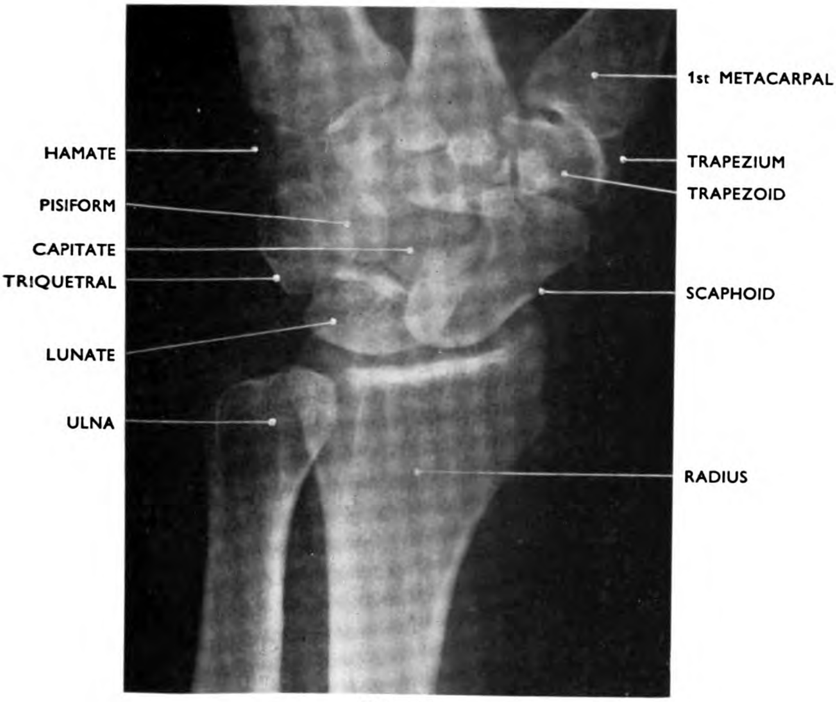


FIG. 16
Left wrist joint: posterior oblique radiograph.

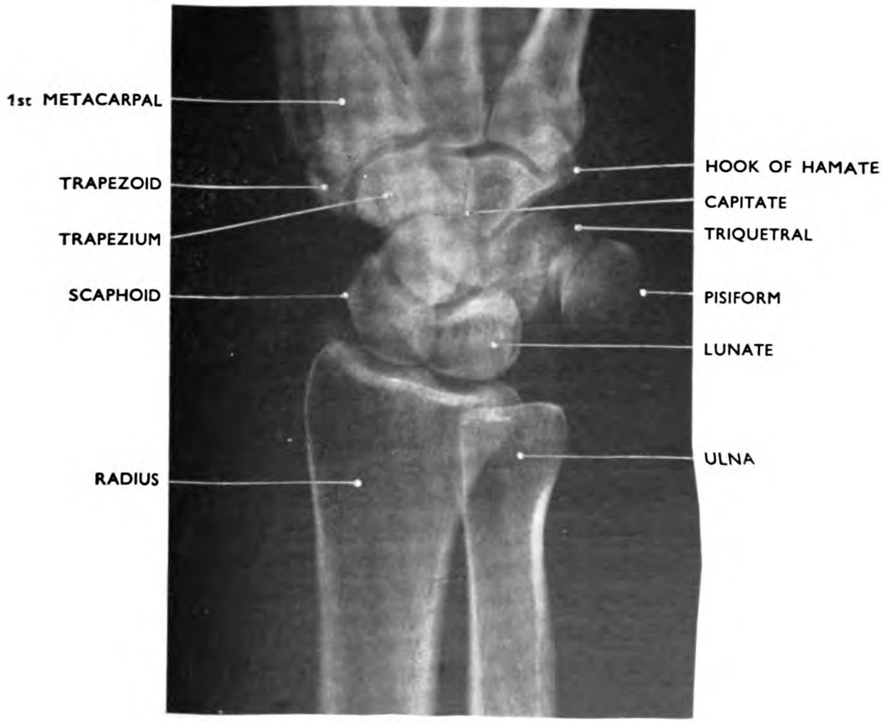


FIG. 17
Left wrist joint: anterior oblique radiograph.

parallel to the film and many hair-line fractures across the waist can only be seen on such a projection. The trapezium is also best demonstrated in this view.

For the anterior oblique radiograph (Fig. 17), the hand is turned 90° from the previous position with the palm facing upward and outward. The pisiform and triquetral are now clearly visible.

Wrist Joint: Postero-anterior Radiograph with deviation of the Hand toward the Ulna (Fig. 18)

This supplementary projection is also used to show injury to the scaphoid. Compare Figure 18 with Figure 12 and observe how deviation of the hand toward the ulna opens out the joint spaces on the lateral side and lengthens the shadow of the scaphoid bone.

FIG. 18

Left wrist joint: postero-anterior radiograph with deviation of the hand toward the ulna.

Ossification of the Bones of the Hand (Fig. 19)

Each **metacarpal and phalanx** ossifies from one primary and one secondary centre. The primary centres for the shafts of the bones appear between the eighth and twelfth weeks of intrauterine life. The secondary centres appear between the second and third years and the epiphyses so formed unite with the shafts about the eighteenth year. It should be noted that whereas the secondary centres for metacarpals 2 to 5 occur at the distal ends of the bones, the centre for the thumb develops at the base.

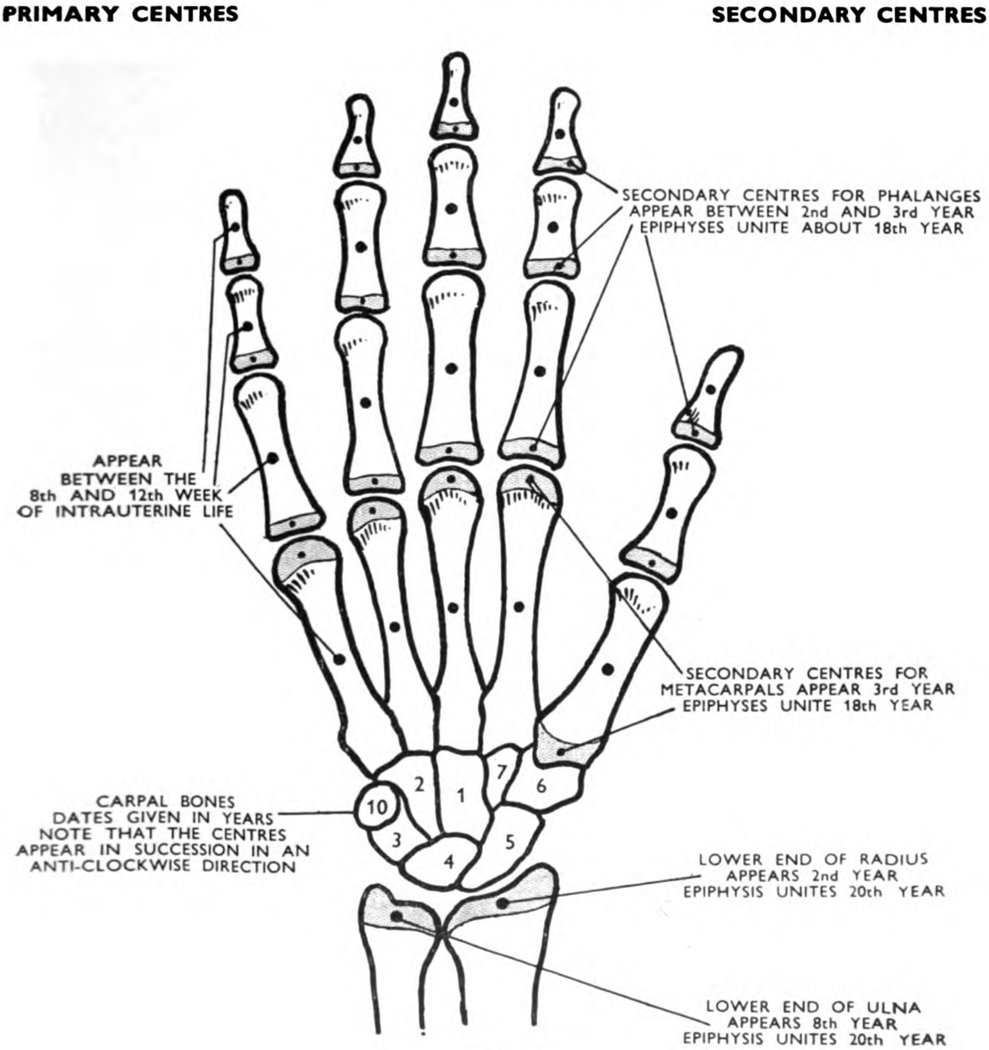


FIG. 19
Ossification of the hand.

The **carpus** shows no ossification at birth. Each bone ossifies from one primary centre in the following order :—

Capitate . . .	1st year	Scaphoid . . .	5th year
Hamate . . .	2nd year	Trapezium . .	6th year
Triquetral . .	3rd year	Trapezoid . .	7th year
Lunate . . .	4th year	Pisiform . . .	10th year

Three radiographs (Figs. 20A to 20C) of the hands show stages in the development of the bones. It should be remembered, however, that there is often a slight variation in ossification dates from one child to another.

2 YEARS

FIG. 20A

Ossification of the hand.

7 YEARS

FIG. 20B

Ossification of the hand.

17 YEARS

FIG. 20C

Ossification of the hand.

FOREARM AND ARM

There are two long bones in the forearm, the radius and the ulna, and one bone in the arm, the humerus. When the hand is supinated the bones of the forearm lie side by side, the radius on the lateral and the ulna on the medial side.

Proximally the radius and ulna articulate with each other and with the humerus to form the elbow joint. Distally they also articulate with each other, but it is the lower end of the radius and the articular disc over the lower end of the ulna which form the wrist joint together with the proximal row of carpal bones.

Radius (Figs. 21 and 22)

The radius consists of a small upper end and a larger lower end, connected by a long shaft.

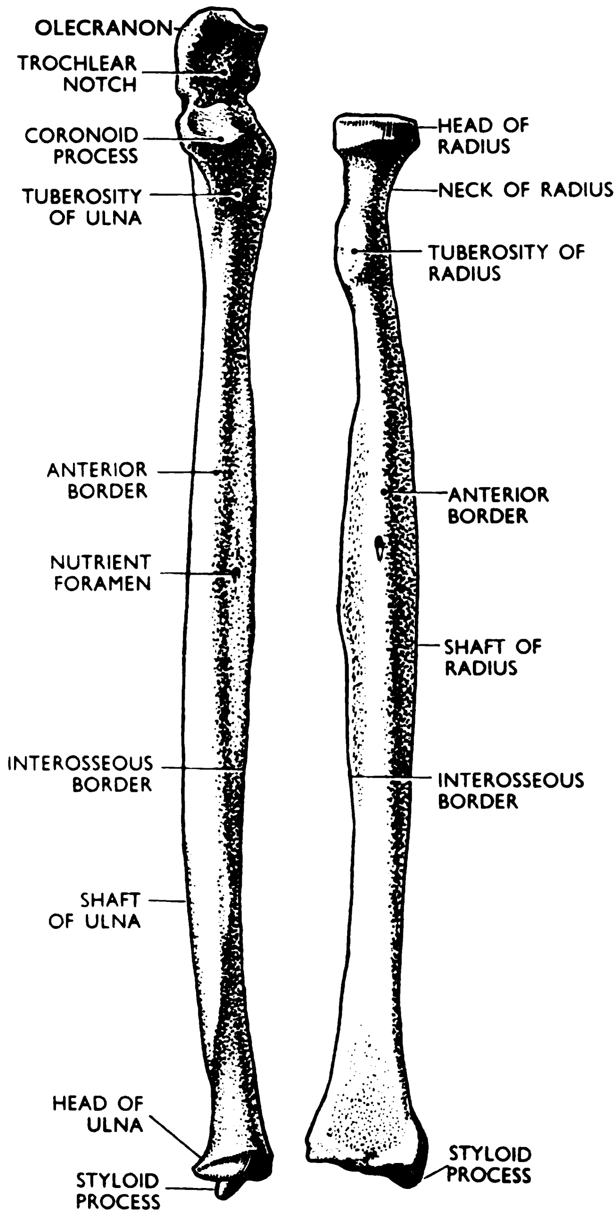


FIG. 21
Left ulna and radius: anterior aspect.

The Upper End presents a head, a neck and a tuberosity.

The **head** of the radius is disc-shaped. The superior surface is concave

for articulation with the capitulum of the humerus on the lateral side of the elbow joint. The circumference of the head articulates with the corresponding

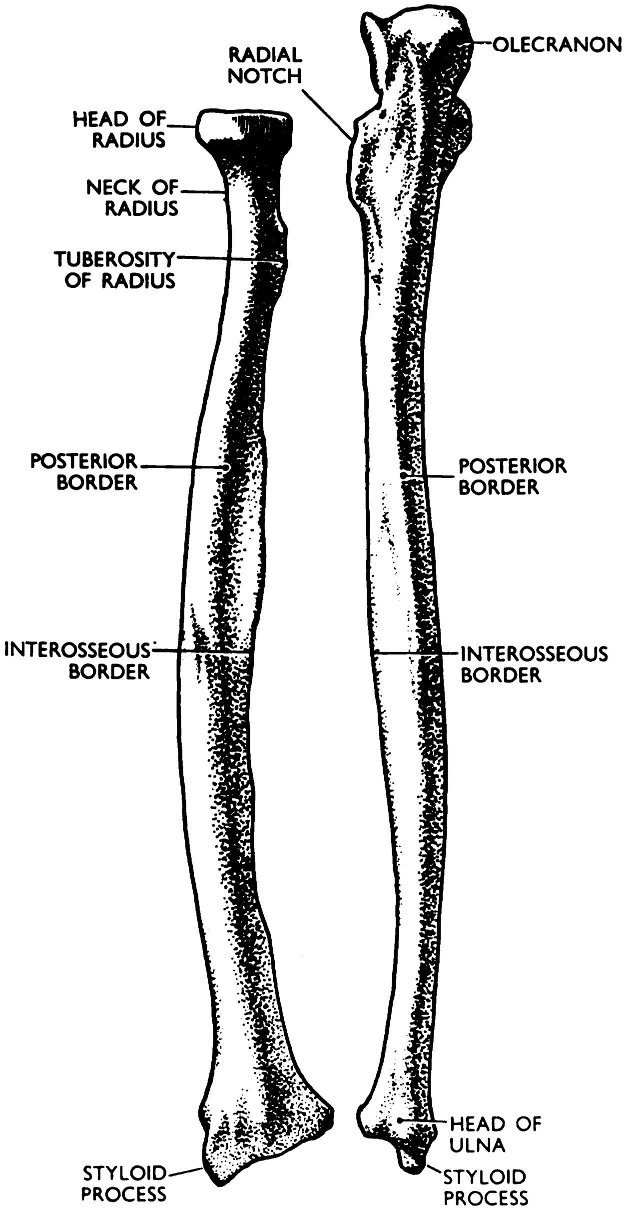


FIG. 22
Left radius and ulna : posterior aspect.

radial notch of the ulna to form the superior radio-ulnar joint. This is a pivot joint and an annular ligament arises from the margins of the radial notch of the ulna to convert the notch into a complete articular ring in which the head of the radius can revolve freely.

The **neck** is the slightly narrowed area immediately below the head.

The **tuberosity** is on the medial side of the bone below the neck, and into its posterior part the tendon of the biceps muscle is inserted.

The **Shaft** of the radius is curved, convex toward its lateral aspect. It is roughly triangular in section and presents three borders—medial, anterior and posterior.

The medial (interosseous) border is a sharp ridge which gives attachment to the interosseous membrane and connects the radius and ulna for three-quarters of their length.

The anterior border begins as an oblique line below the radial tuberosity; it is indistinct at the middle of the shaft, but becomes clearly defined on the lateral side of the lower end.

The posterior border is only clearly defined in the middle third of the shaft.

The middle of the anterior surface is pierced by a nutrient artery which transmits blood-vessels to the interior of the bone; this foramen can sometimes be seen passing obliquely upward in antero-posterior radiographs. The lateral and posterior surfaces do not present any notable bony features.

The Lower End of the radius is the widest part of the bone and is roughly quadrilateral on cross-section, thus presenting four surfaces.

On the medial surface is the **ulnar notch,** where the head of the ulna articulates to form the distal radio-ulnar joint.

The lateral surface projects distally beyond the remainder of the bone to form the **radial styloid process,** which is easily palpable and serves as a useful landmark in radiography.

The anterior surface, at first smooth and concave, ends distally in a prominent ridge.

The posterior surface is marked by a series of ridges and grooves for the extensor muscle tendons passing from the forearm to the hand.

The distal articular surface of the radius is divided by a faint ridge into a quadrilateral medial and a triangular lateral facet. The medial facet articulates with the lunate bone; the triangular lateral facet encroaches on to the surface of the styloid process and articulates with the scaphoid.

The main bony features which enable the student to distinguish the left radius from the right are:—

1. The anterior surface of the broad distal end is concave.
2. In contrast, the posterior surface of the distal end is ridged for the extensor tendons.
3. The styloid process lies on the lateral side of the distal end.

Ulna (Figs. 21 and 22)

The ulna consists of a large upper end and a smaller lower end or head connected by a long shaft.

The Upper End consists of two large bony prominences, the olecranon and the coronoid process, between which is the trochlear notch.

The **olecranon** is the very prominent projection on the proximal end of the ulna. Its posterior margin, which is roughly triangular, can be felt easily and forms the subcutaneous tip of the elbow.

The **coronoid process** is smaller and projects forward from the anterior surface of the bone below the olecranon. On its anterior surface is a roughened tuberosity into which the tendon of the brachialis muscle is inserted.

The **trochlear notch** is a deep semilunar articular surface between the olecranon and the coronoid process. This articular surface is divided by a vertical ridge into a larger medial and a smaller lateral surface and thus conforms to the shape of the trochlea of the humerus with which it articulates. Since the elbow joint is a hinge joint the movements permitted between the trochlear articular surface and the humerus are solely those of flexion and extension.

The **radial notch** is a small depressed articular surface on the lateral aspect of the coronoid process. It articulates with the head of the radius, and to its anterior and posterior margins is attached the annular ligament which embraces the head of the radius.

The **Shaft** has a slight convexity toward the medial side in its lower half, making separation of the radius and ulna widest at that level when the hand and forearm are supinated. The shaft is triangular in cross-section, similar to that of the radius, and thus presents three borders—anterior, posterior and lateral. These borders separate the anterior, posterior and medial surfaces.

The anterior border is thick and rounded. It extends from just below the coronoid process to the styloid process.

The posterior border begins at the posterior end of the olecranon process and is indistinct in the lower third of the shaft; this border can be felt through the skin.

The lateral or interosseous border is sharply defined and faces the sharp medial border of the radius.

The Lower End of the ulna consists of a head and a styloid process.

The **head** is small. On its lateral side is a small surface for articulation with the radius at the distal radio-ulnar joint. An articular disc is interposed between the inferior surface of the head and the adjacent carpal bone—the triquetral.

The **styloid process** is small and projects distally from the medial side of the head. This bony protuberance can be felt easily through the skin and lies about 1 cm. proximal to that of the radius.

The main bony features which enable the student to distinguish the left ulna from the right are:—

1. The trochlear notch lies on the anterior upper aspect of the bone.
2. The radial notch is placed on the lateral side of the trochlear notch.

Humerus (Fig. 23)

The humerus is the only bone in the upper arm and is the largest and longest bone in the whole upper limb. It consists of a proximal end, which forms the

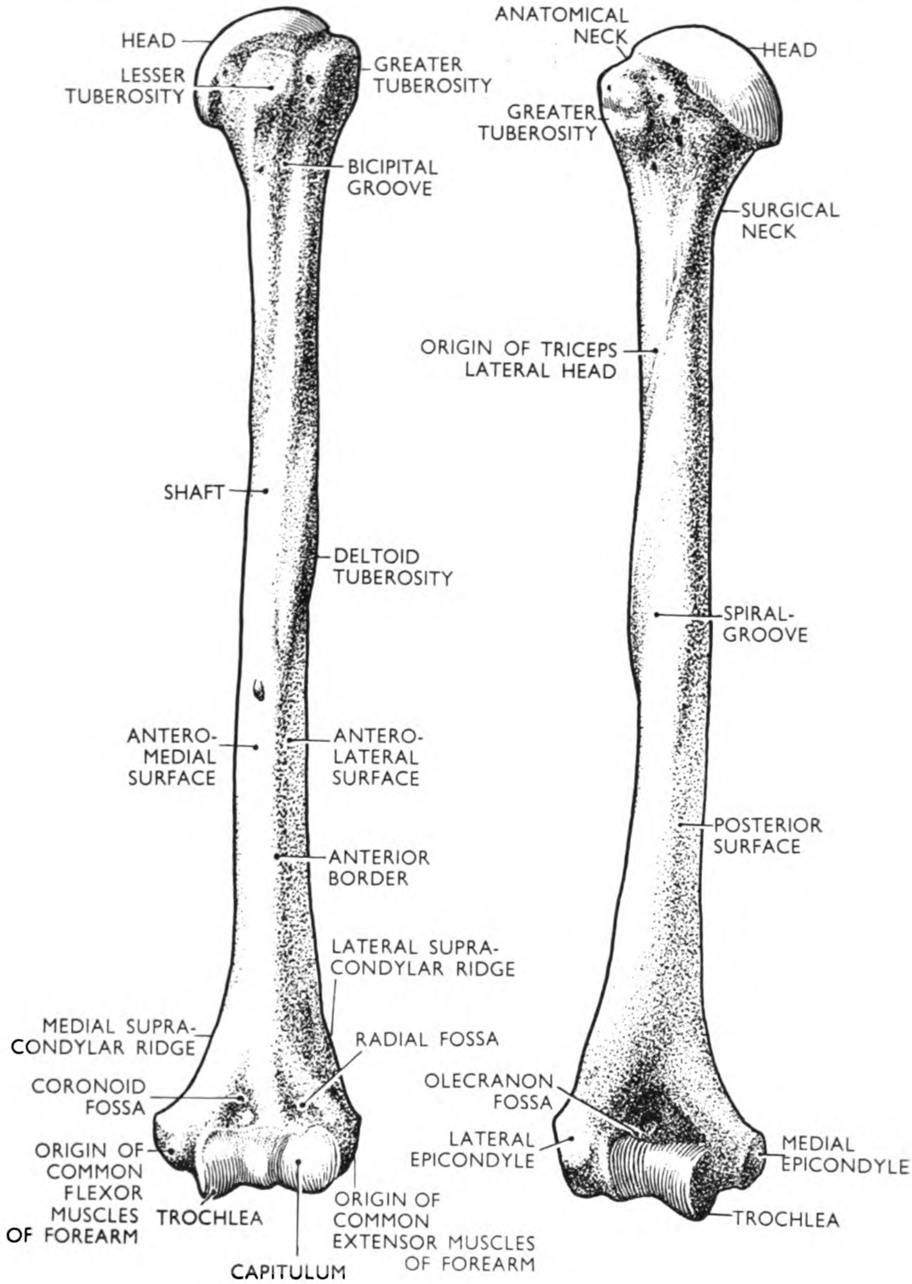


FIG. 23
Left humerus: posterior aspect.

shoulder joint with the scapula, a long cylindrical shaft and a distal end, which articulates with the radius and ulna to form the elbow joint.

The Upper End includes the head, the greater and lesser tuberosities. The **head** is smooth and rounded, forming about one-third of a sphere. It is directed upward, inward and slightly backward when the arm is at rest beside the trunk. The head is covered with articular cartilage and articulates with the glenoid cavity of the scapula at the shoulder joint. It is separated from the shaft by the anatomical neck.

The **greater tuberosity** is situated on the lateral side of the upper end of the humerus. It is flattened postero-superiorly and gives attachment to the supraspinatus, infraspinatus and teres minor muscles which arise from the scapula.

The **lesser tuberosity** is placed on the anterior aspect of the bone just below the anatomical neck and gives attachment to the subscapularis muscle.

The **surgical neck,** where fractures frequently occur, is situated at the upper end of the shaft about an inch below the tuberosities.

The **bicipital groove** lies between the greater and lesser tuberosities and is a vertical channel in which runs the tendon of the long head of the biceps. The pectoralis major muscle is attached to the lateral lip of the groove, while the latissimus dorsi and teres major muscles are inserted chiefly into the medial lip.

The Shaft of the humerus generally is cylindrical in shape, but is flattened and widened transversely at its lower end. It has three borders—anterior, medial and lateral. The anterior border begins as the lateral margin of the bicipital groove and becomes ill defined and rounded toward the lower end. The medial border begins as the medial margin of the bicipital groove and at its lower end runs into the medial supracondylar ridge. The lateral border is ill defined superiorly, but inferiorly becomes continuous with the lateral supracondylar ridge. The centre of this border is crossed by a depression, running obliquely forward and downward—the spiral groove—along which passes the radial nerve.

Only the antero-lateral and antero-medial surfaces present any notable bone features. A small bony protuberance, the deltoid tuberosity, is situated about the middle of the antero-lateral surface, and at a similar level the antero-medial surface is pierced by a nutrient foramen, running obliquely downward.

The Lower End of the humerus, or condyle, is expanded from side to side, and the lateral margins project as prominent epicondyles with corresponding well-defined supracondylar ridges above.

The **medial epicondyle** is easily palpable on the medial side of the elbow; the ulnar nerve crosses its smooth posterior surface, and in this situation it can be pressed against the bone to produce the sensation of ‘ pins and needles ’ in the hand. The superficial flexor muscles of the forearm arise from the anterior surface of the medial epicondyle.

The **lateral epicondyle** is smaller and less prominent than the medial epicondyle. The superficial extensor muscles of the forearm arise from its anterior surface.

The lower or articular surface of the condyle is divided into an outer part, the capitulum, and an inner larger part, the trochlea.

The **capitulum** is rounded and its articular surface is placed anteriorly and inferiorly; it articulates with the head of the radius.

The **trochlea** is the larger pulley-shaped articular surface which extends from the posterior to the anterior aspect of the bone. The two margins of the trochlea are of unequal size. The larger medial lip influences the 'carrying angle,' *i.e.*, the angle between the long axis of the humerus and that of the supinated extended forearm; this angle is approximately 170° on the lateral side.

The **coronoid** and **radial fossae** are two depressions on the anterior aspect of the humerus, above the trochlea and capitulum. On flexion of the forearm, these depressions accommodate the coronoid process and head of the radius respectively.

The **olecranon fossa** is a deep depression on the posterior aspect of the humerus, just above the trochlea. On extension of the forearm, this fossa receives the olecranon.

RADIOGRAPHIC APPEARANCES OF THE FOREARM AND ARM

Elbow Joint: Antero-posterior Radiograph (Fig. 24)

This radiograph is taken with the forearm fully extended on the upper arm. The centring point is over the joint space, which lies 1 inch below the level of the epicondyles of the humerus.

The transversely expanded lower end of the humerus is seen face-on in this view. The supracondylar ridges end at the prominent epicondyles, below which is the slightly narrower articular area with the rounded capitulum on its lateral side and the pulley-shaped trochlea on the medial side. The medial lip of the trochlea is seen to be more prominent than the lateral lip, and this results in slight outward angulation of the ulna and the radius on the humerus (the 'carrying angle').

Between the humeral epicondyles and immediately above the trochlea is the combined shadow of the olecranon and coronoid fossae, visible as a relatively transradiant area since the bone here is much thinner. The radial fossa above the capitulum is less obvious radiographically, since it is small and shallow. The articular surfaces of the radius and the ulna are the reverse shape of the opposing capitulum and trochlea. The disc-shaped head of the radius is seen in profile and the concavity of its superior surface, which opposes the convexity of the capitulum, is evident. The neck of the radius and the

radial tuberosity partly overshadow the adjacent ulna. The coronoid process is seen below the trochlea and on its lateral margin is the radial notch in which the head of the radius rotates; the annular ligament is not visible. Immediately

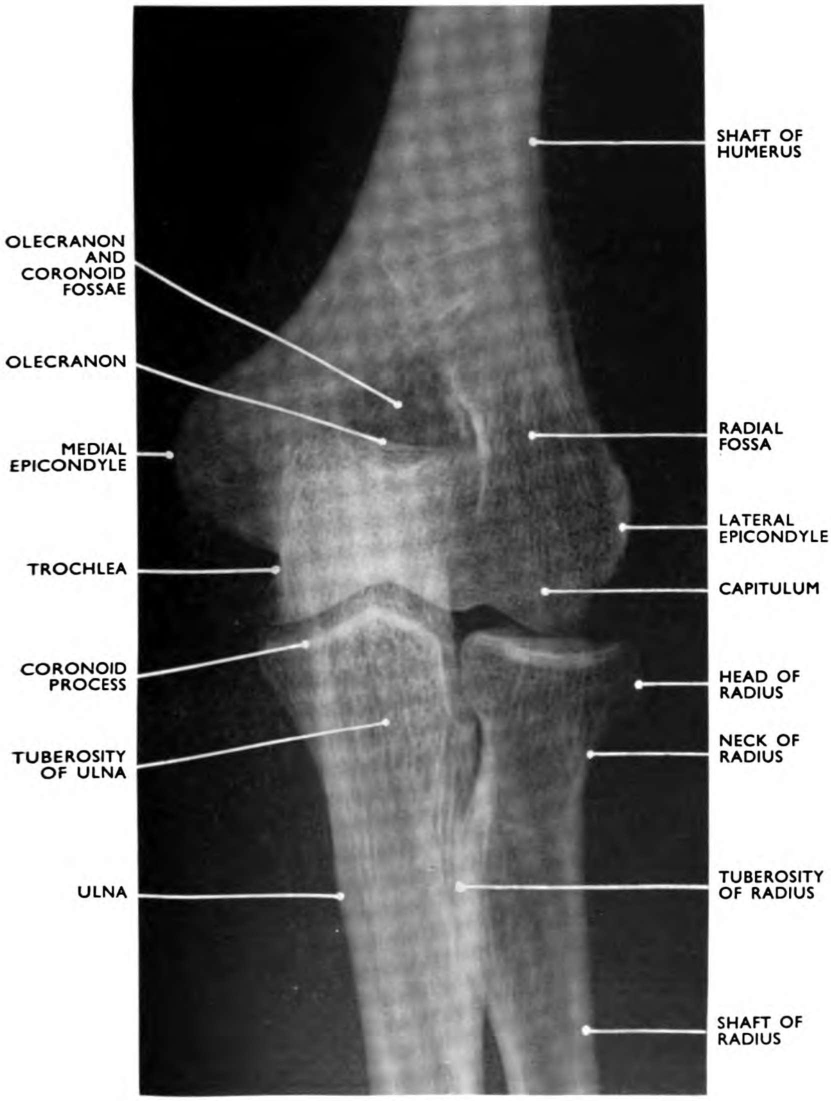


FIG. 24
Left elbow joint: antero-posterior radiograph.

below the coronoid process of the ulna the roughened area of the tuberosity can be distinguished by the slight irregularity of bone texture. The olecranon is overshadowed by the lower end of the humerus, but it can be appreciated in this radiographic position that it fits into the olecranon fossa when the arm is extended.

Elbow Joint: Lateral Radiograph (Fig. 25)

For this radiographic view the elbow is flexed to 90° and the hand placed in the lateral position. The lower end of the humerus is seen to be of fairly uniform width in this lateral projection; the combined shadows of the trochlea and capitulum form the rounded articular end of the humerus, which is set slightly forward of the main line of the shaft. The epicondyles of the humerus

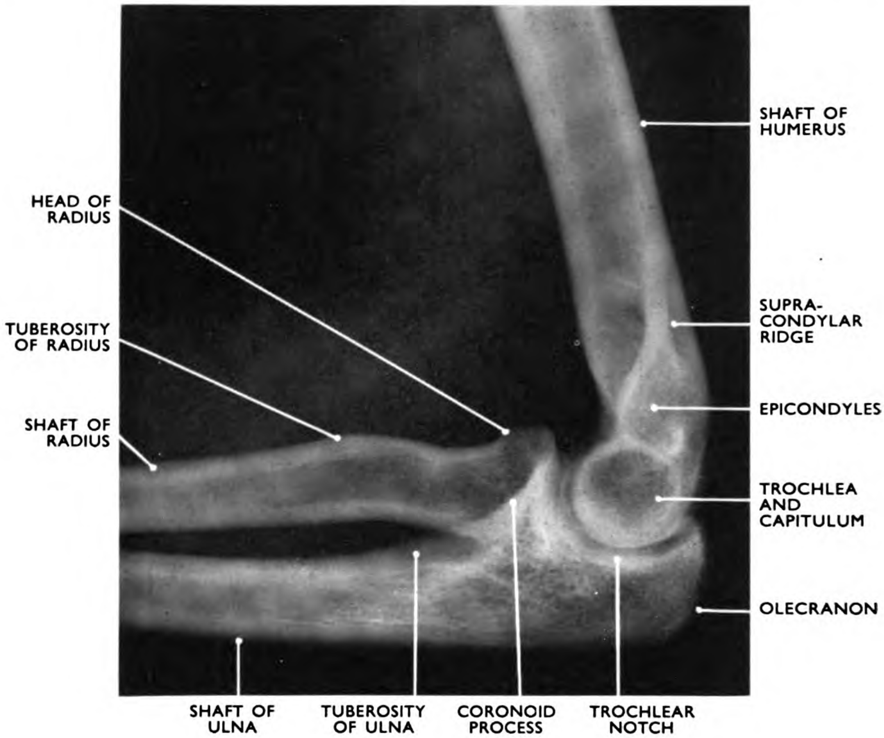


FIG. 25
Left elbow joint: lateral radiograph.

are also superimposed to produce a denser shadow at the junction of the rounded articular end and the shaft.

The trochlear notch of the ulna and the olecranon and coronoid process are seen in profile, although the coronoid process is partly overshadowed by the head of the radius. Immediately below the neck of the radius the tuberosity of the radius is clearly visible, since it is now seen in profile. It will be appreciated from this radiograph that the upper end of the radius lies slightly anterior to the ulna at the elbow joint.

Additional Radiograph for Examination of the Head of the Radius (Fig. 26)

The head of the radius is a common site of fracture and on both the

antero-posterior and the lateral views of the elbow joint it is partly overshadowed by the ulna. Slight outward rotation of the arm separates the bones and gives a clearer view of the head of the radius and the radial notch of the ulna (compare Figs. 24 and 26).

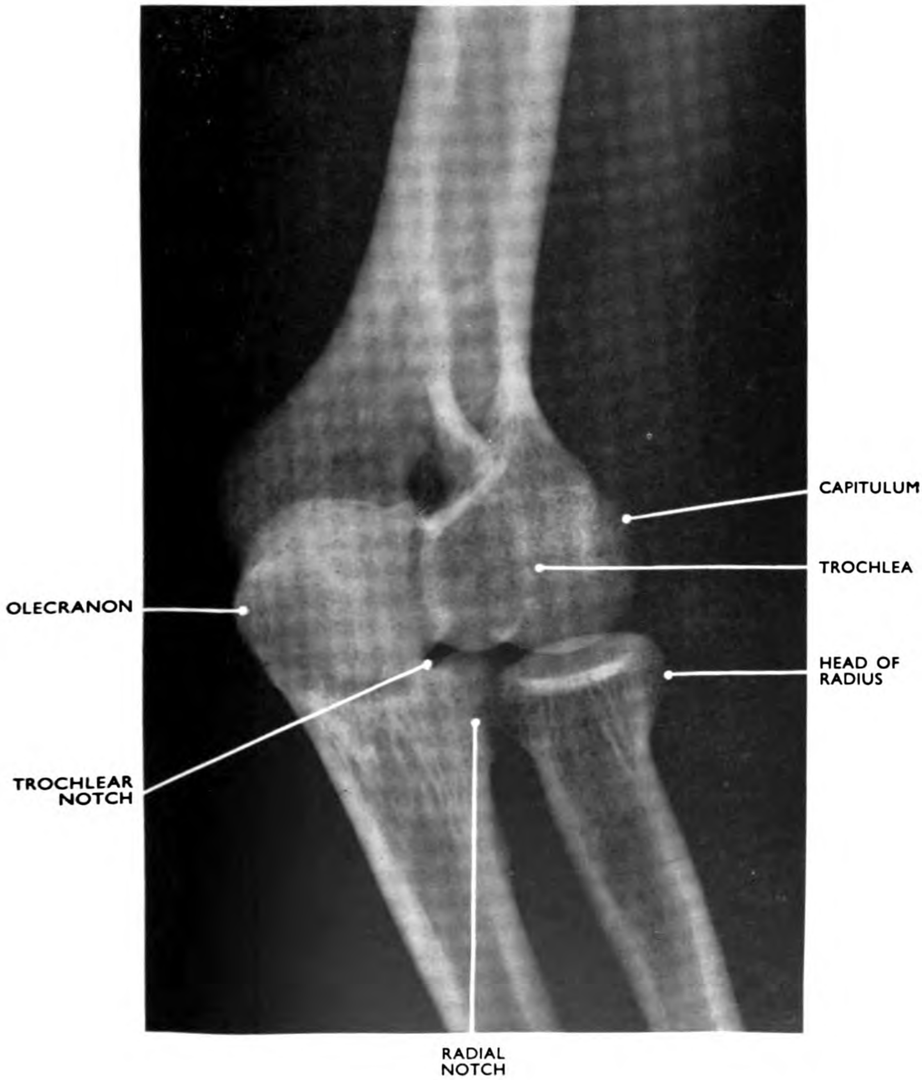


FIG. 26

Left elbow joint: oblique radiograph.

Forearm: Antero-posterior and Lateral Radiographs (Figs. 27 and 28)

These two full-length radiographs of the forearm demonstrate the main features of the shafts of the radius and ulna.

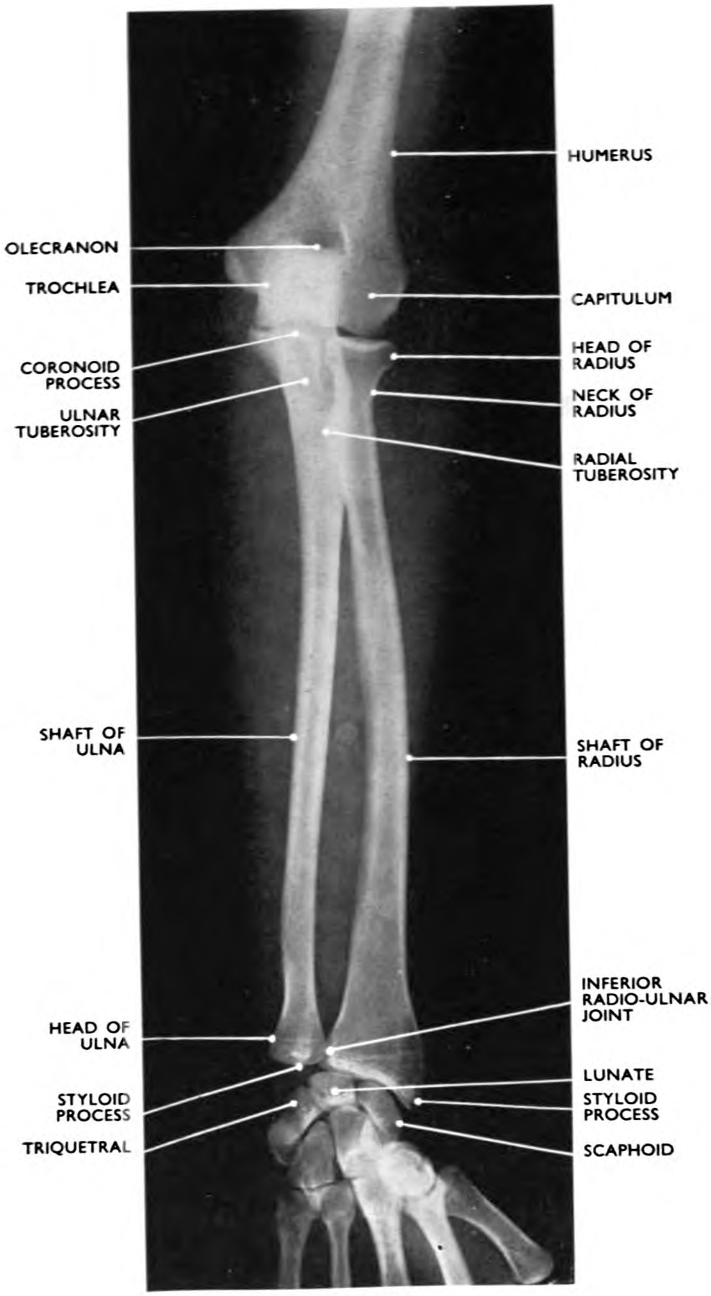


FIG. 27
Left forearm: antero-posterior radiograph.

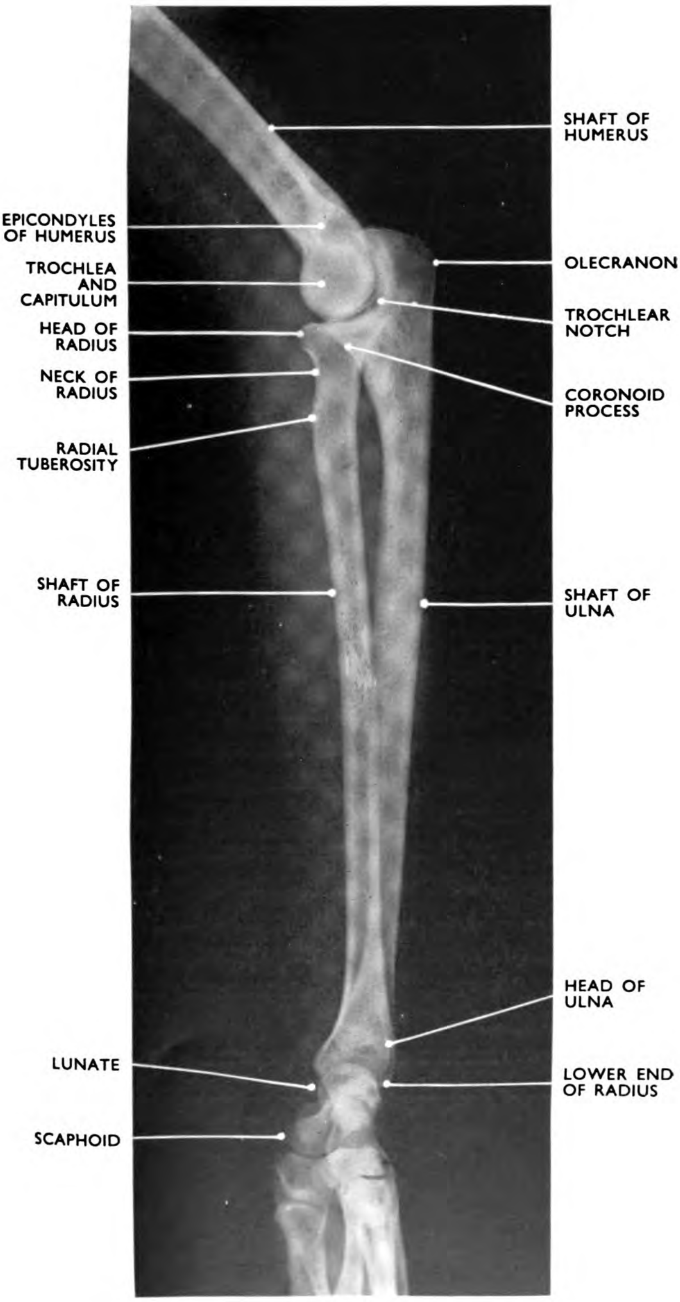


FIG. 28
Left forearm: lateral radiograph.

In the **antero-posterior radiograph** (Fig. 27) the slight bowing of the shafts of the radius and ulna is clearly seen; this divergence is most marked in the distal half of the forearm. The sharp interosseous borders face one another in the midshaft region and are seen in profile; the interosseous membrane does not cast a shadow.

The **lateral radiograph** (Fig. 28) demonstrates that the upper end of the radius lies anterior to the ulna at the elbow joint, but distally they converge to lie in the same plane at the wrist joint.

Humerus: Antero-posterior Radiograph (Fig. 29)

This large bone is difficult to demonstrate on one radiograph, mainly due to the difference in density between the head surrounded by the shoulder muscles and the thinner lower end. The arm is placed in an antero-posterior position in relationship to the X-ray tube and film; the hand is supinated and the arm slightly abducted to clear it from the shadow of the chest wall.

The smooth, almost hemispherical, articular surface of the head of the humerus faces medially and slightly upward; it overlaps the glenoid cavity of the scapula in this view since the shoulder joint is slightly oblique to the rays. The anatomical neck of the humerus is seen as a faint linear density running obliquely across the bone at the base of the articular surface; the capsular ligaments of the shoulder joint are attached to the bone just outside this line. On the lateral aspect of the head the greater tuberosity is seen in profile, and toward the centre of the bone is a curved line of denser bone, the lesser tuberosity; between the tuberosities is the bicipital groove. Note the position of the surgical neck just below the level of the tuberosities.

The long cylindrical shaft has a uniform radiographic appearance apart from the slight prominence of the deltoid tuberosity on the lateral aspect of the midshaft. Below the deltoid tuberosity is the spiral groove, but this cannot be identified radiographically. At the distal end of the shaft the bone widens transversely with the appearance of the supracondylar ridges which extend downward to the epicondyles.

The radiographic appearances of the lower end of the humerus are similar to those seen in the antero-posterior radiograph of the elbow joint.

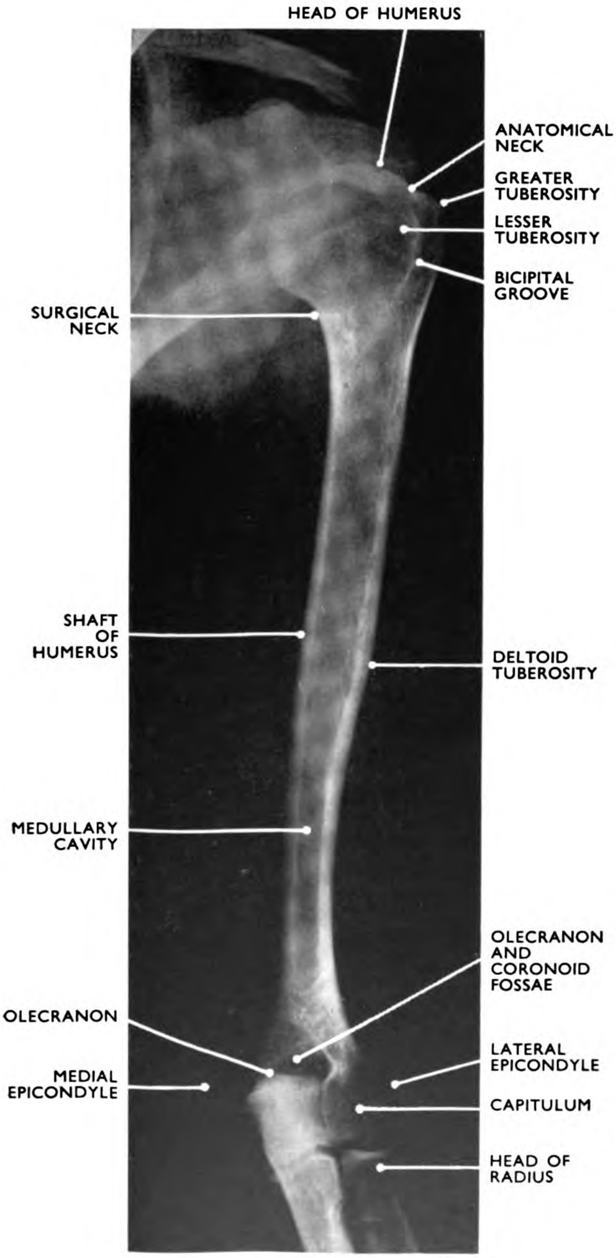


FIG. 29
Left humerus: antero-posterior radiograph.

Humerus : Lateral Radiograph (Fig. 30)

If, proceeding from the position for the antero-posterior radiograph of the humerus, the arm is flexed at the elbow and the hand placed in front of the body the humerus turns through 90° into the lateral position. Although

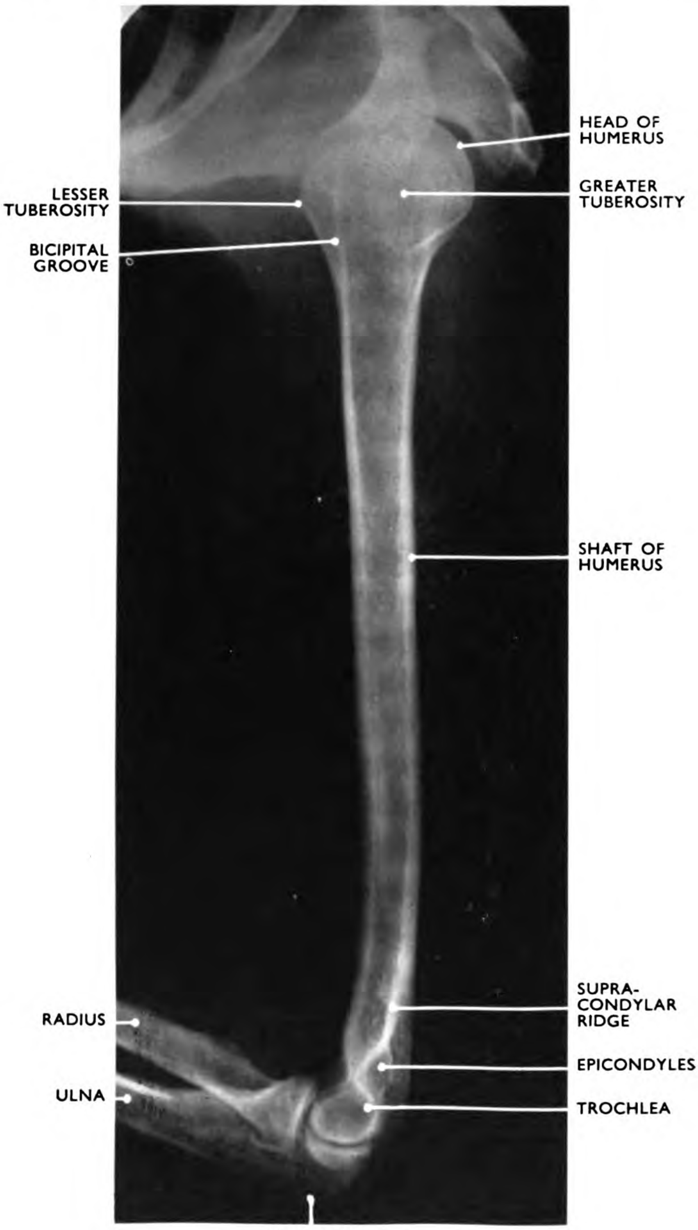


FIG. 30
Left humerus : lateral radiograph.

the lower end of the humerus is lateral, which can be appreciated from the superimposition of the epicondyles and articular surfaces, it will be seen that the head is directed slightly backward from the true lateral position. The lesser tuberosity is now visible in profile on the anterior aspect of the upper end of the bone, and the greater tuberosity is face-on, with the bicipital groove between. The shaft is devoid of bony landmarks, since the deltoid tuberosity is no longer prominent. The appearances at the lower end of the humerus are similar to those seen on the lateral radiograph of the elbow joint.

Ossification of the Bones of the Arm and Forearm (Figs. 31 and 32)

The primary centres of ossification for the shafts of the humerus, radius and ulna appear about the eighth week of intrauterine life, and at birth ossification of the shafts is well advanced (Fig. 32A).

The secondary centres develop later and at different ages (Fig. 31).

The **upper end of the humerus** is ossified from three separate secondary centres—one each for the head, the greater and the lesser tuberosity. These centres join together to form a single large epiphysis about the sixth year, and it fuses with the shaft between the eighteenth and twentieth years.

The **lower end of the humerus** is ossified from four secondary centres—one each for the medial and lateral epicondyles, the trochlea and the capitulum. The centres appear between the second and the twelfth year and those for the lateral epicondyle, trochlea and capitulum join together to form a large epiphysis which unites with the shaft between the sixteenth and eighteenth years. The secondary centre for the medial epicondyle forms a separate epiphysis which unites with the shaft about the twentieth year; without a knowledge of the secondary centres this relatively late fusing epiphysis could be mistaken for a fracture.

A secondary centre appears in the head of the **radius** about the fourth year and in the olecranon of the **ulna** at the eleventh year; the epiphyses so formed unite with the shafts between the sixteenth and eighteenth years. The secondary centres at the lower ends of the radius and ulna appear earlier and these epiphyses fuse later than those at the upper end. The centre for the radius appears at the end of the first year and that for the ulna at the eighth year; the resultant epiphyses fuse with the shafts at the twentieth year.

The development of the epiphyses at the elbow joint can be seen in the series of radiographs (Figs. 32A to 32C) of children of different ages.

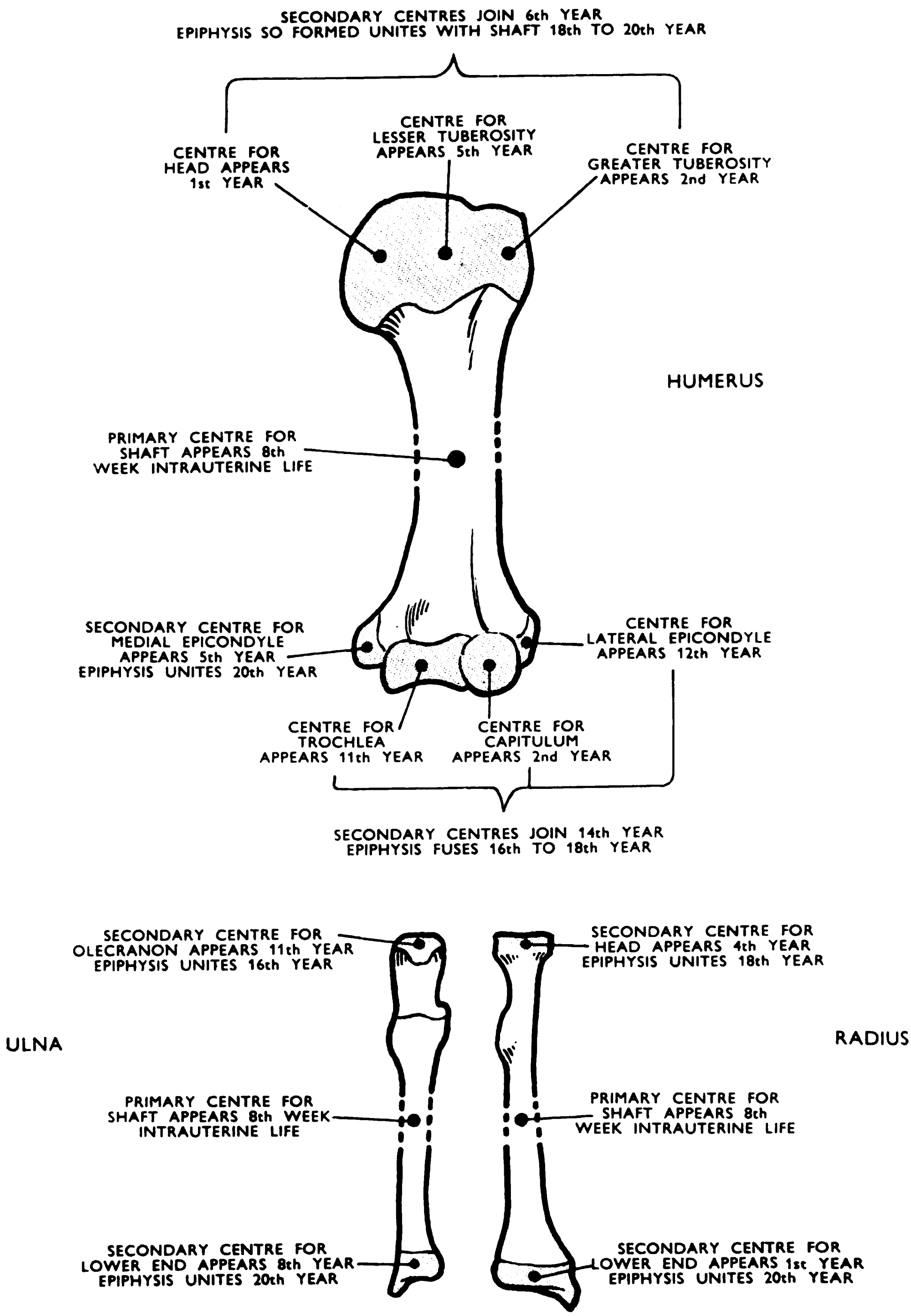


FIG. 31

Ossification of humerus, radius and ulna.

AT BIRTH

FIG. 32A
Ossification of humerus, radius and ulna.

7 YEARS

FIG. 32B
Ossification at elbow joint.

15 YEARS

FIG. 32C
Ossification at elbow joint.

SHOULDER GIRDLE

The shoulder girdle consists of the scapula and the clavicle. The girdle is attached anteriorly to the sternum, but posteriorly there is no bony connection with the trunk. The scapula is situated on the upper postero-lateral aspect of the thorax to which it is attached by muscles only. It articulates with the humerus at the shoulder joint. The clavicle lies almost horizontally, high up on the anterior wall of the thorax and is subcutaneous throughout its length. The outer end of the clavicle articulates with the scapula and the inner end with the sternum; thus it supports the shoulder clear of the trunk to give the upper limb freedom of movement, and to a large extent it transmits the weight of the upper limb to the trunk, thus preventing undue strain on the muscles.

Scapula (Figs. 33, 34 and 35)

The scapula is a flat bone, triangular in shape, and has a costal or anterior surface and a dorsal or posterior surface. It has three borders—superior, medial and lateral; at the junction of these borders are the superior, inferior and

lateral angles. The lateral angle is flattened and massive; it is often referred to as the head of the scapula and has on its lateral aspect the glenoid cavity for articulation with the head of the humerus. The shelf-like spine crosses the posterior (dorsal) surface in an upward and outward direction, and its

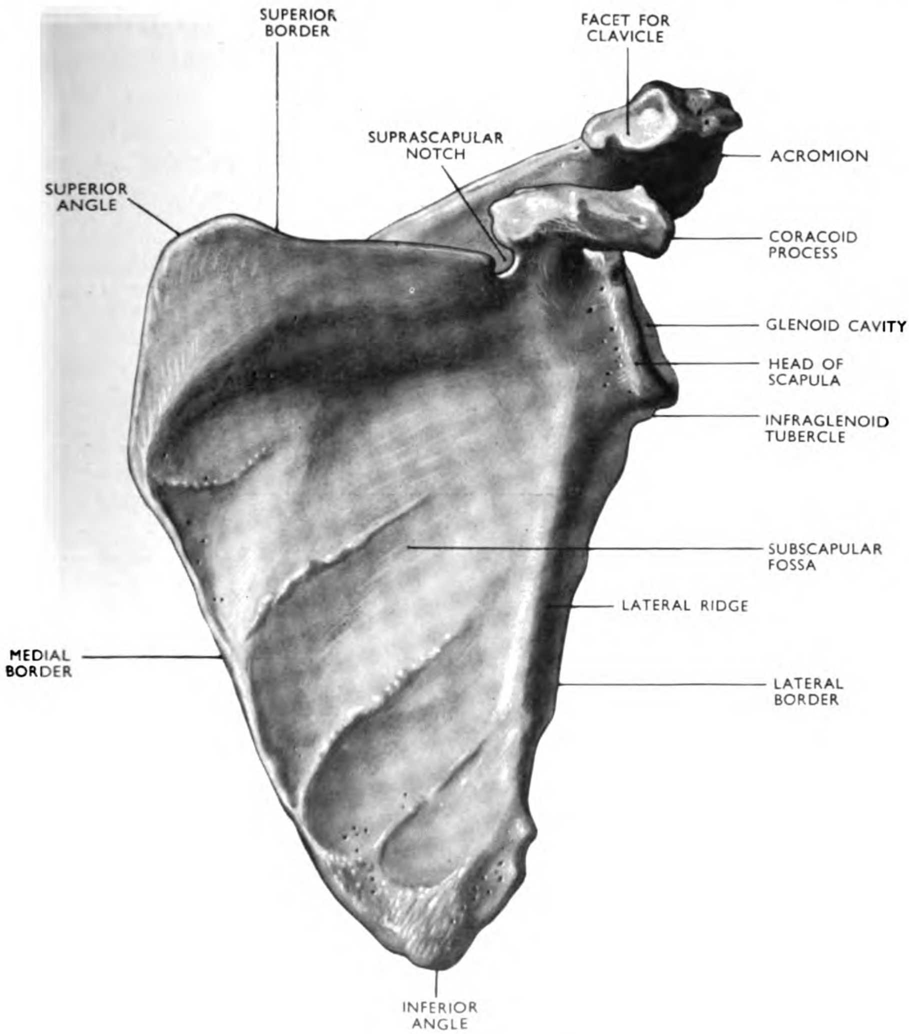


FIG. 33
Left scapula: anterior (costal) surface.

continuation forms the acromion. These features should enable the student to assign a scapula to the correct side of the body.

The **anterior (costal) surface** (Fig. 33) faces forward and slightly medially in the living subject when the arm is by the side. It is gently concave and conforms roughly to the curvature of the chest wall. It is crossed by a number of ridges for the attachment of the subscapularis muscle. A thickened ridge

of bone runs parallel to the lateral border and is most prominent at its upper end, immediately below the glenoid cavity.

The **posterior (dorsal) surface** (Fig. 34) faces backward and outward. It is crossed by the spine of the scapula which divides it into the supraspinous

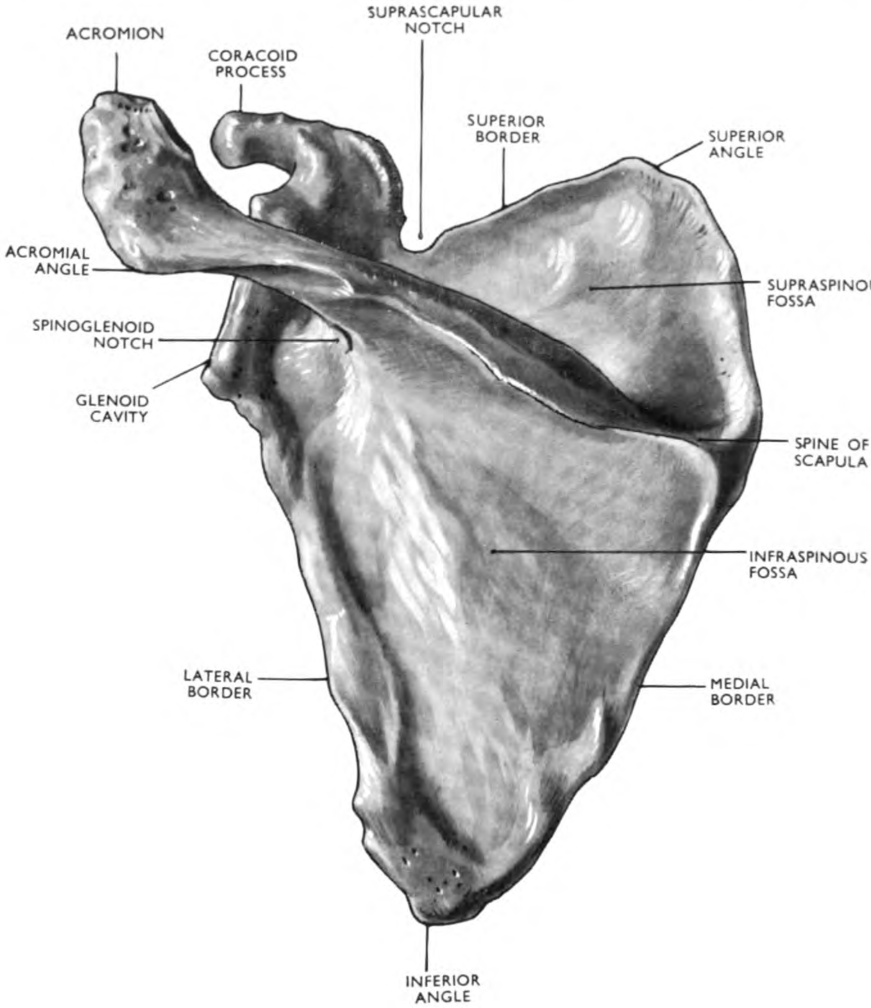


FIG. 34
Left scapula: posterior (dorsal) surface.

fossa above and the infraspinous fossa below. The spine ends just short of the head of the scapula, and in the angle so formed between the lateral edge of the spine and the neck of the scapula is the spinoglenoid notch. The two fossae can only communicate with each other through this notch.

The **superior border** is the shortest. At its lateral end is a small indentation, the suprascapular notch; beyond this the beak-like coracoid process

projects forward and outward and gives attachment to the short head of the biceps and coracobrachialis muscles and ligaments which stabilise the acromio-clavicular joint.

The **medial (vertebral) border** runs parallel to the vertebral column when the arm is by the side. It can be felt through the skin for most of its length.

The **lateral (axillary) border** is the roughened edge lateral to the thickened ridge on the costal surface. This border is so well covered by muscles that it can only be felt near the inferior angle.

The **superior angle** is at the junction of the superior and medial borders. It lies almost level with the midpoint of the clavicle when the arm is by the side, and since it can be felt through the skin it is used as a centring point for the postero-anterior projection of the clavicle.

The **inferior angle** is at the junction of the medial and lateral borders and is more acute than the superior angle. It lies over the posterior end of the seventh rib and is easily palpated.

The **lateral angle** is thick, since it carries the head of the scapula and the glenoid cavity. Immediately behind the head is a slight constriction, the neck of the scapula.

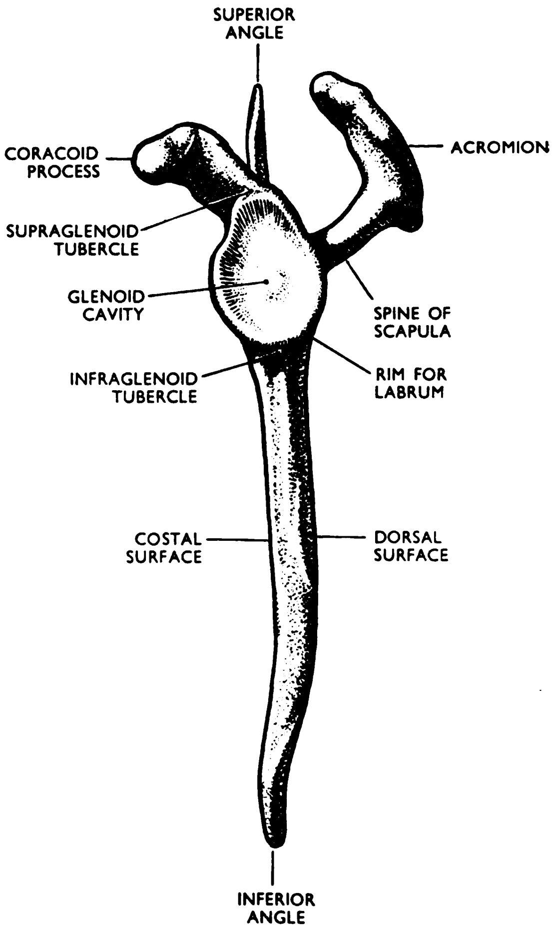


FIG. 35
Left scapula: lateral aspect.

The **glenoid cavity** is a pear-shaped articular surface which is gently concave (Fig. 35). It faces in a lateral direction with a slight upward and forward tilt. The glenoid labrum is a fibrocartilaginous rim attached to the periphery of the glenoid cavity; it deepens the cavity of the joint slightly. The shallow socket and the comparatively large humeral head permit great freedom of movement, but render this ball-and-socket joint unstable. The joint capsule is thin and hangs loosely inferiorly and the ligaments are also weak. The stability of the joint depends mainly on surrounding muscles and it is a common site of dislocation. The supraglenoid and infraglenoid tubercles are small areas of

roughened bone immediately above and below the glenoid cavity; they are the sites of attachment for the long head of the biceps and triceps muscles respectively.

The **coracoid process** arises from the lateral end of the superior border of the scapula, adjacent to the superior margin of the head. It projects upward and forward and then turns sharply laterally over the superior aspect of the shoulder joint. The tip of this process can be felt on deep pressure in a depression, the infraclavicular fossa, which lies below the outer third of the clavicle under the anterior border of the deltoid muscle. The ligaments and muscles attached to the process have been mentioned previously.

The **spine** of the scapula is a thin shelf of bone on the posterior surface. It runs outward and slightly upward from the vertebral border to end by becoming continuous with the acromion and separates the supraspinous and infraspinous fossae. The crest of the spine is roughened and gives attachment to the trapezius and deltoid muscles; it can be felt through the skin throughout its length.

The **acromion** is the flattened lateral projection of the crest of the spine. Its plane is roughly at right angles to the spine and it extends laterally to overhang the shoulder joint. Its lateral border is continuous with the inferior border of the crest of the spine, and at their junction is the acromial angle. The medial border of the acromion is continuous with the superior border of the crest of the spine, and at its anterior end there is a small oval articular facet which articulates with the clavicle to form the acromio-clavicular joint. These features can be felt through the skin. The coraco-acromial ligament is attached between the acromion and the coracoid process and is a protective shelf above the shoulder joint.

Clavicle (Figs. 36 and 37)

This bone differs from other long bones because it has no medullary cavity. It consists of a shaft and an outer and an inner end. The shaft has two curves;

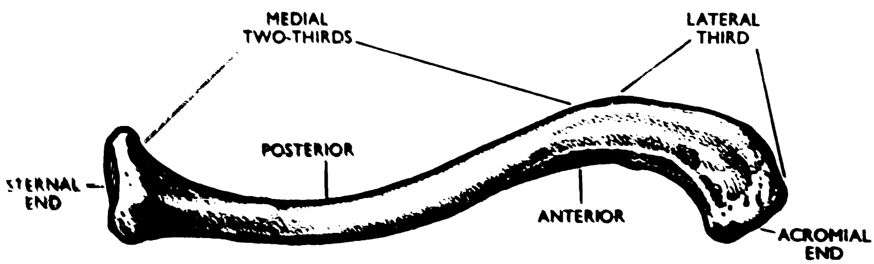


Fig. 36
Left clavicle: upper surface.

the medial part is convex forward and the lateral part concave forward. The medial or sternal end is enlarged; the lateral or acromial end is flattened and

its under surface presents two small bony prominences. These features should enable the student to determine the side to which a clavicle belongs.

The **medial two-thirds of the shaft** is rounded and on its inferior surface near the sternal end there is a slightly depressed roughened area for the insertion of the costoclavicular ligament which joins the clavicle to the first rib and first costal cartilage.

The **lateral one-third of the shaft** is flattened. Its anterior border is concave

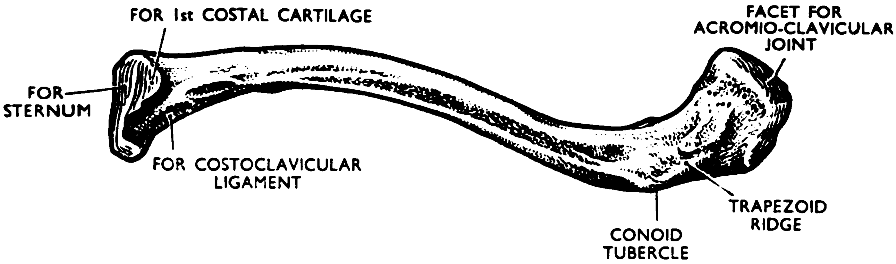


FIG. 37
Left clavicle: lower surface.

and gives attachment to the deltoid muscle; the posterior border is convex and part of the trapezius muscle is inserted into it. On the inferior surface is a small prominence, the conoid tubercle, from which a ridge extends laterally; the tubercle and the ridge give attachment to important ligaments which prevent upward dislocation of the clavicle at the acromio-clavicular joint.

The **sternal end** of the clavicle is thickened and forms a prominent bony landmark at the base of the neck. This end of the clavicle articulates with the clavicular notch of the manubrium sterni, and also with the first costal cartilage to form the sterno-clavicular joint; the articular cartilage covers the medial and inferior surfaces of the bone.

RADIOGRAPHIC APPEARANCES OF THE SHOULDER GIRDLE

Shoulder Joint and Scapula: Antero-posterior Radiograph (Fig. 38)

This radiograph is taken with the trunk slightly rotated so that the shoulder under examination is in contact with the film. The arm is slightly abducted to clear the trunk and the forearm supinated.

The coracoid process is used as the centring point to cover the relatively wide radiographic field of the examination and this results in obliquity of the shoulder joint to the central ray; the head of the humerus, therefore, partly overshadows the shallow glenoid cavity and no clear joint space is visible. The glenoid labrum and the capsular ligaments do not cast any shadow in the normal joint.

The position of the arm results in an antero-posterior projection of the head of the humerus and the greater tuberosity is seen in profile on the lateral margin

of the head. A curved line of denser bone toward the centre of the upper end is the shadow cast by the lateral margin of the lesser tuberosity. The bicipital groove lies on the lateral edge of the lesser tuberosity.

The medial part of the body of the scapula is overshadowed by the thorax, and the medial border may be difficult to identify since it is thin and is crossed by the shadows of the ribs and lung tissues. The relatively thick lateral border

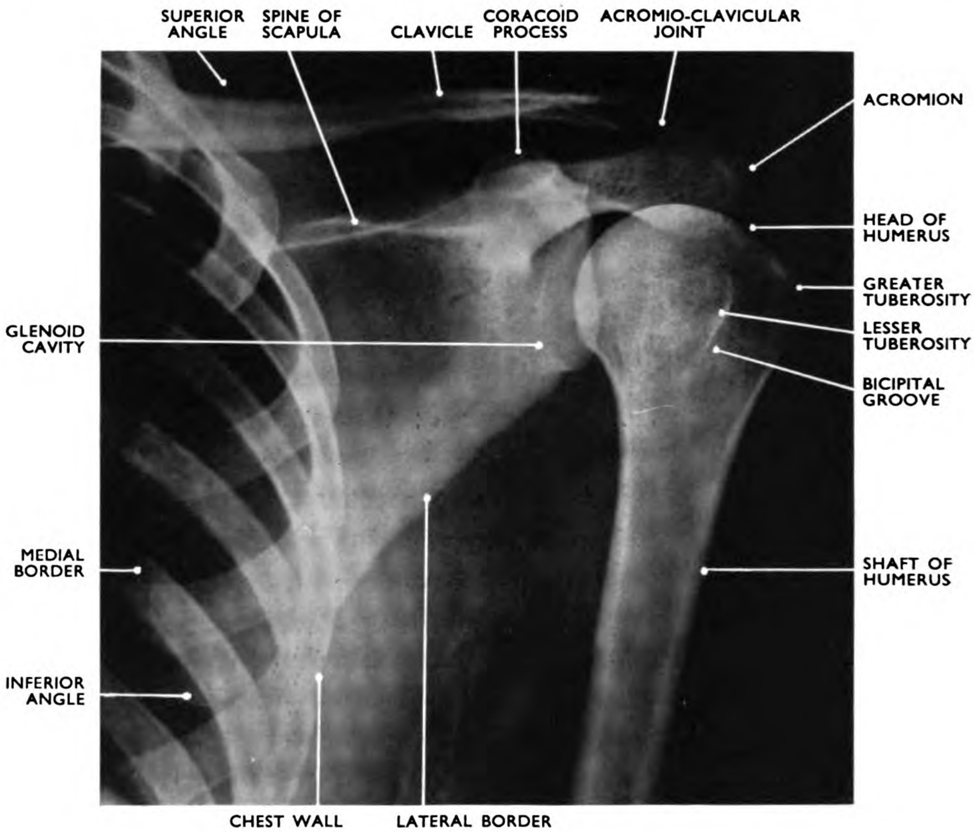


FIG. 38
Left shoulder joint and scapula: antero-posterior radiograph.

of the scapula is easily seen, since it is largely clear of the chest wall; if it is followed down from the glenoid cavity, the inferior angle of the scapula can be identified, usually at the level of the seventh rib or seventh intercostal space. The slightly irregular medial border runs upward from the inferior to the superior angle, which lies behind the medial third of the clavicle. The short superior border ends laterally at the base of the coracoid process, seen end-on as an oval shadow of denser bone; the tip of the coracoid process projects downward and outward over the upper part of the neck of the scapula.

The junction of the spine and body of the scapula is visible as a horizontal line of denser bone extending medially from the neck of the scapula just below

the shadow of the coracoid process; at its outer end is the lateral free edge of the spine at the spinoglenoid notch. Medially it is crossed by two parallel oblique lines which are the shadows cast by the upper and lower margins of the crest of the spine. The twist of the spine can be appreciated by a study of these lines.

The acromion is clearly seen to be the free lateral projection of the spine. This flattened process is seen almost face-on in this radiographic position and partly overshadows the head of the humerus. The short medial border of the acromion and the outer end of the clavicle oppose each other at the acromio-clavicular joint, and the role of the clavicle in supporting the shoulder clear of the trunk can be appreciated.

Movements at the Shoulder Joint

Figure 39, A to D is a series of radiographs taken as the arm was raised laterally until above the head. These radiographs demonstrate the relative movements of the humerus and scapula.

It will be seen that relatively little movement of the scapula takes place

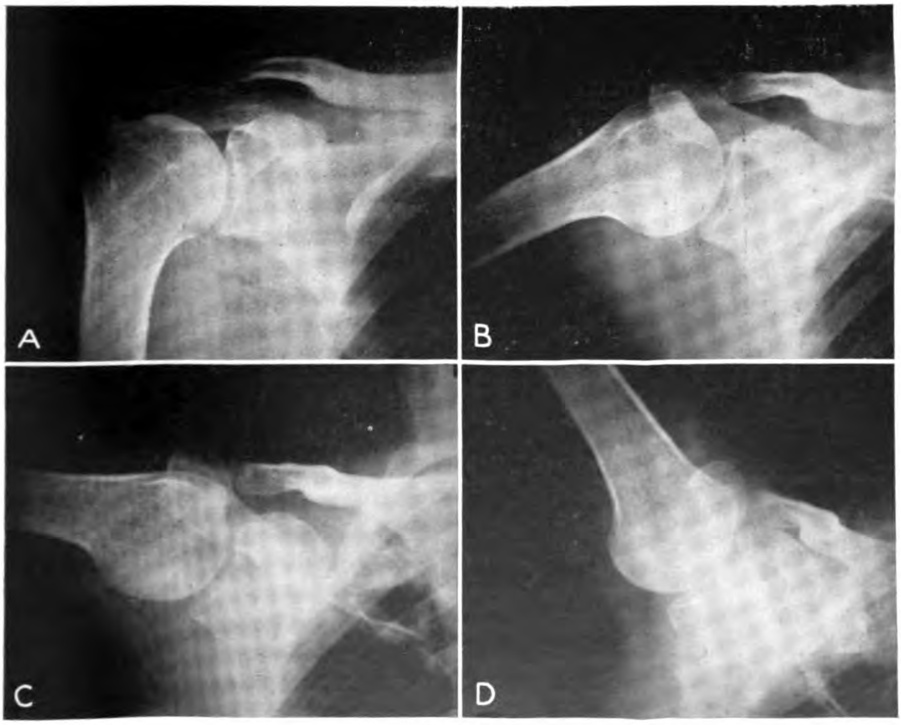


FIG. 39

Series of radiographs to show movement at the shoulder joint during abduction of the arm.

until the arm is almost at right angles to the trunk (Fig. 39, A to C). Thereafter further elevation of the arm is largely accomplished by rotation of the scapula

on the trunk (Fig. 39, D). This final phase is also accompanied by lateral rotation of the humerus, so it is now seen in the lateral position.

Shoulder Joint : Antero-posterior Radiograph to show the Joint Space (Fig. 40)

In the radiograph of the ' general view ' (Fig. 38) of the shoulder area the head of the humerus overshadows the glenoid cavity. To separate these two shadows and to see the joint space clearly with the glenoid cavity in profile, increased rotation of the trunk is necessary.

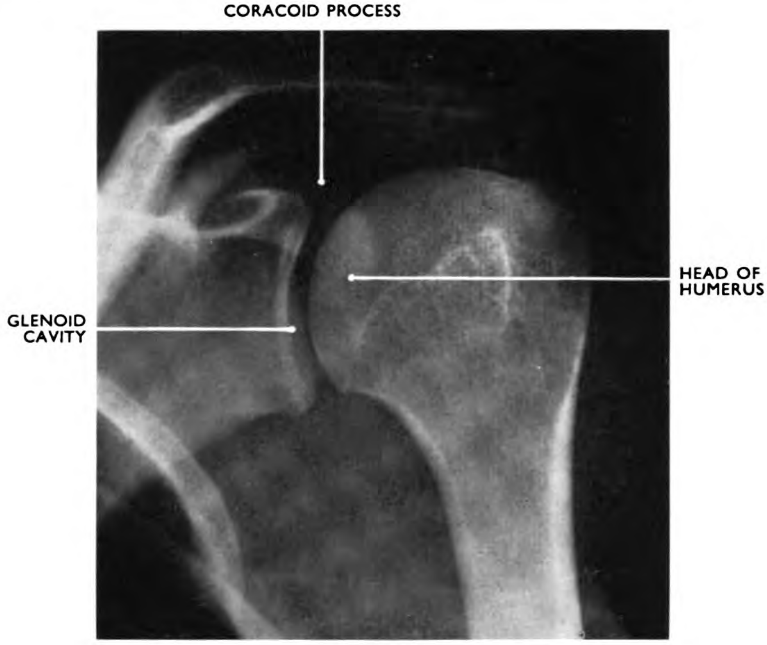


FIG. 40
Left shoulder joint : antero-posterior radiograph to show the joint space.

Scapula : Lateral Radiograph (Fig. 41)

A lateral view of the scapula is obtained by rotating the trunk from the postero-anterior into an oblique position with the scapula under examination nearest the film. The rotation should bring the plane of the scapula at about 75° to the film, but by centring medially on the thoracic vertebrae the oblique ray will produce a true lateral projection.

The body of the scapula is seen edge-on, separated from the chest wall by the thickness of the muscles. The concavity of the costal surface of the body and the projecting spine on the posterior aspect give it a triradiate appearance. The glenoid cavity, here seen face-on, occupies the centre of the radiating arms, but is overshadowed by the relatively larger head of the humerus. The lesser tuberosity of the humerus is seen in profile, directed

medially toward the chest wall. Abduction of the arm during positioning serves to separate the shaft of the humerus and the lower part of the body of the scapula.

The prominent spine of the scapula is surmounted by the acromion, which

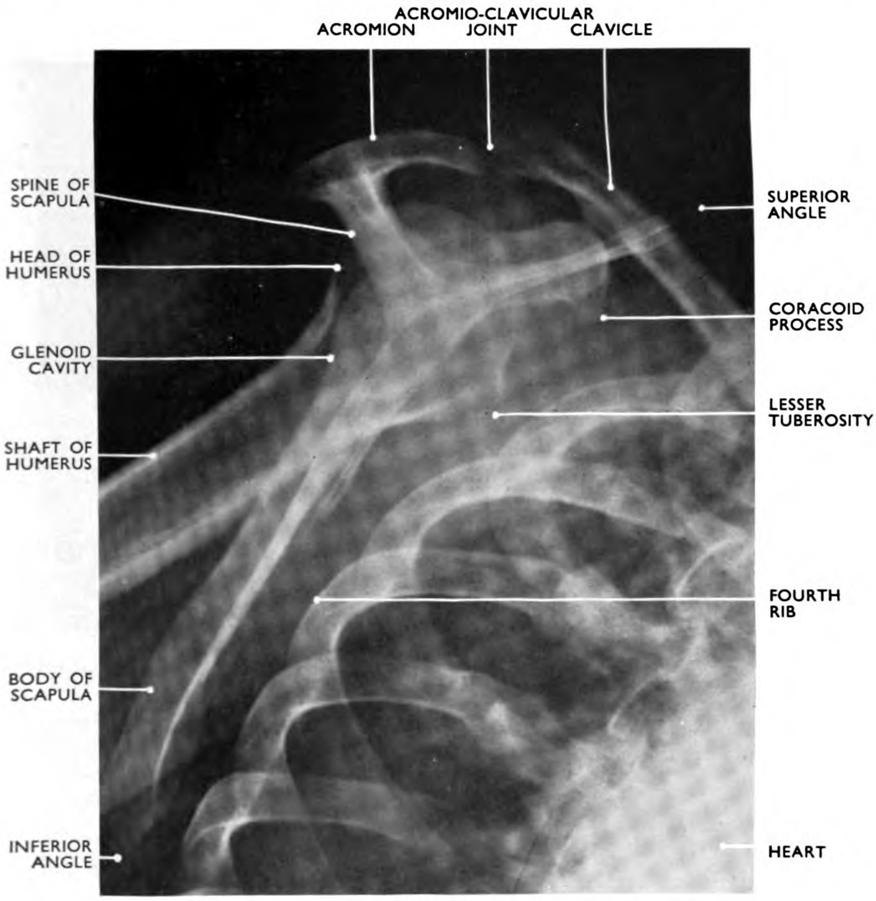


FIG. 41
Left scapula : lateral radiograph.

projects upward and forward almost at a right angle, producing the appearance of an inverted boot. The clavicle arches upward and backward over the chest wall to articulate with the acromion at the acromio-clavicular joint.

The shadows of the relatively massive coracoid process and the thin upper part of the body of the scapula are superimposed; the tip of the coracoid process can be seen to turn acutely forward.

Clavicle : Antero-posterior and Postero-anterior Radiographs (Figs. 42 and 43)

These two radiographic projections are complementary in demonstrating the main anatomical features, but both show that the clavicle does not possess

a medullary cavity; spongy bone extends throughout the interior of the shaft enclosed by a thin outer layer of compact bone.

The **antero-posterior radiograph** (Fig. 42) demonstrates the double curve of the clavicle. The acromio-clavicular joint is clearly seen and the conoid tubercle is a prominent feature on the inferior aspect of the outer third of the shaft. The view of the shoulder joint is similar to that seen in the 'general' antero-posterior radiograph (Fig. 38) but, due to the more medial position of the centring point, the tip of the coracoid process now overshadows the shoulder joint. The suprascapular notch is also visible.

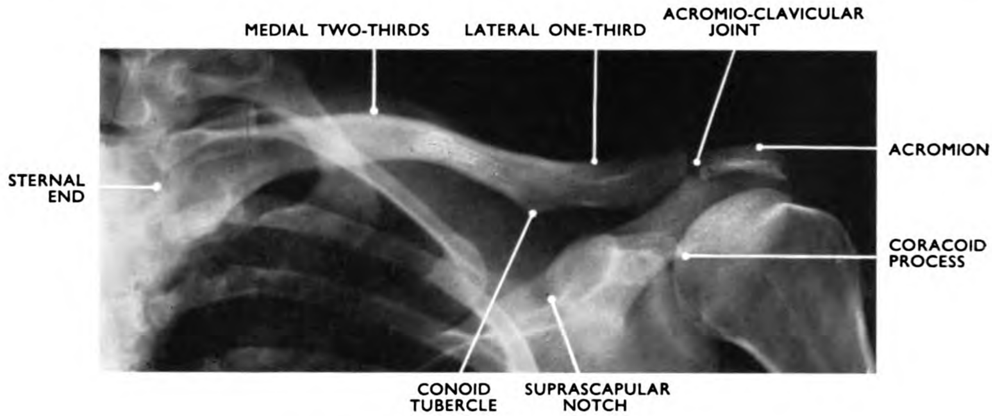


FIG. 42
Left clavicle: antero-posterior radiograph.

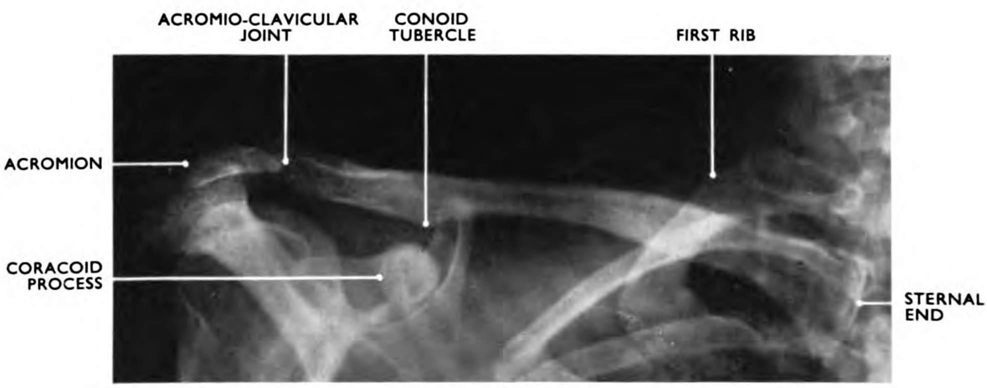


FIG. 43
Left clavicle: postero-anterior radiograph.

The **postero-anterior radiograph** (Fig. 43) shows the sternal end of the clavicle more clearly, since it is considerably nearer the film in the postero-anterior position than in the antero-posterior position; however, in both

projections it is largely overshadowed by the denser vertebral column. In this radiograph the body of the scapula is very oblique, almost end-on; the head of the humerus is now seen from the lateral aspect, as the arm is rotated during positioning so that the palm of the hand faces backward.

Sterno-clavicular Joints: Postero-anterior Radiographs (Figs. 44 and 45)

In taking radiographs of the sterno-clavicular joints, difficulty is experienced in separating the shadows of the joints from the denser shadows of the vertebral column; the sterno-clavicular joint nearest the film is clearly demonstrated

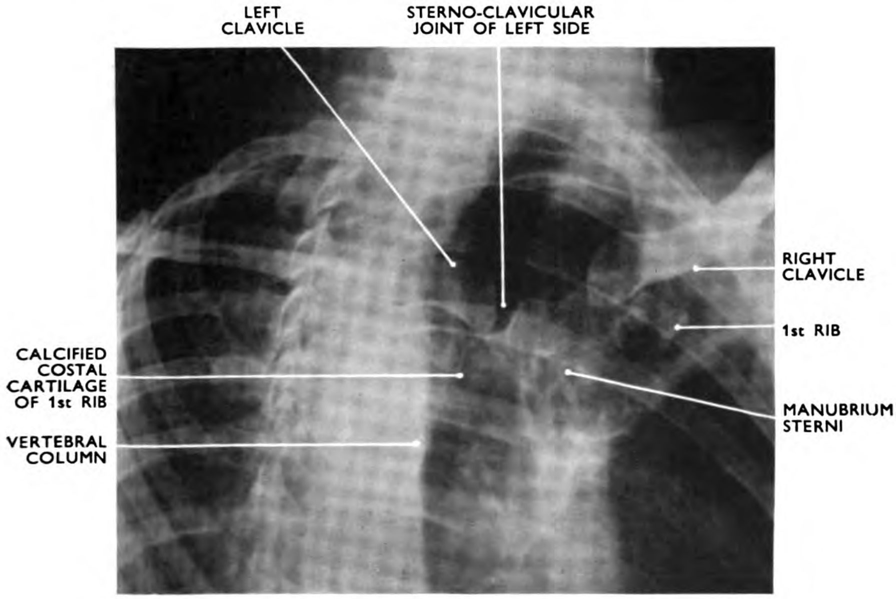


FIG. 44
Left sterno-clavicular joint: postero-anterior radiograph trunk rotated. (From "tube aspect.")

when the trunk is rotated 45° to the film, but the contralateral joint is now oblique and is partly obscured by the foreshortened image of the clavicle of the side farthest from the film (Fig. 44).

Another method is to keep the trunk in the postero-anterior position in relationship to the film and to tilt the tube inward and toward the sternum (Fig. 45). In this case the joint of the side from which the tube is tilted will be clearly shown, whilst the contralateral joint will be obscured by the vertebral column.

In both methods the shadow of the fourth and fifth ribs will cross the area of the joint, obscuring it to a slight extent.

It should be noted in the radiographs that the articular end of the clavicle

is considerably larger than that of the opposing surface of the sternum. The joint space appears wider than that of most other joints, due to the interposition of a cartilaginous articular disc which, in fact, completely divides the joint cavity into two parts.

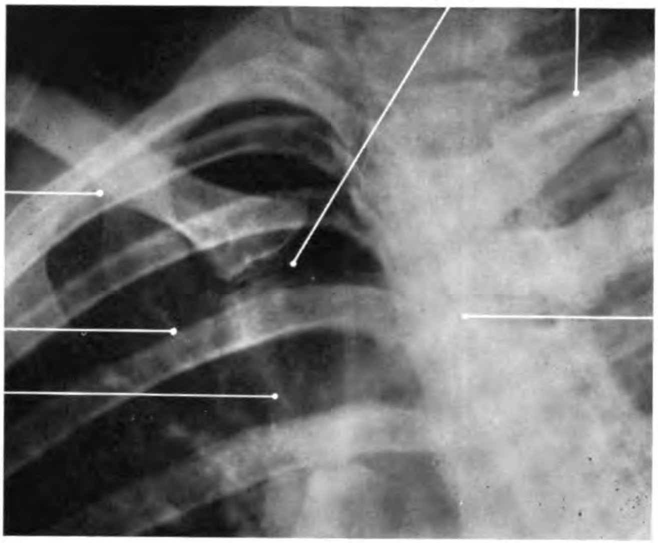


FIG. 45
Left sterno-clavicular joint: postero-anterior radiograph tube tilted. (From "tube aspect.")

Ossification of the Bones of the Shoulder Girdle (Fig. 46)

The **scapula** ossifies from eight centres. The primary centre for the body and spine appears near the glenoid cavity in the eighth week of intrauterine life. Seven secondary centres appear after birth. The secondary centre for the coracoid process appears during the first year and the epiphysis unites with the body at about the fifteenth year. The remaining secondary centres are: one for the subcoracoid region, two for the acromion, one for the inferior angle, one for the medial border and one for the lower part of the glenoid cavity; these centres appear at puberty or shortly after and the epiphyses fuse about the twenty-fifth year.

The **clavicle** is the first bone in the body to ossify. Ossification begins in membrane from two primary centres in the shaft of the bone in the fifth week of intrauterine life; these two centres fuse to form one centre one or two weeks later. A secondary centre develops in the sternal end of the bone between the eighteenth and twentieth years; fusion of this epiphysis with the shaft does not take place until the twenty-fifth year, and the epiphyseal line is still visible in radiographs of young adults (Fig. 47).

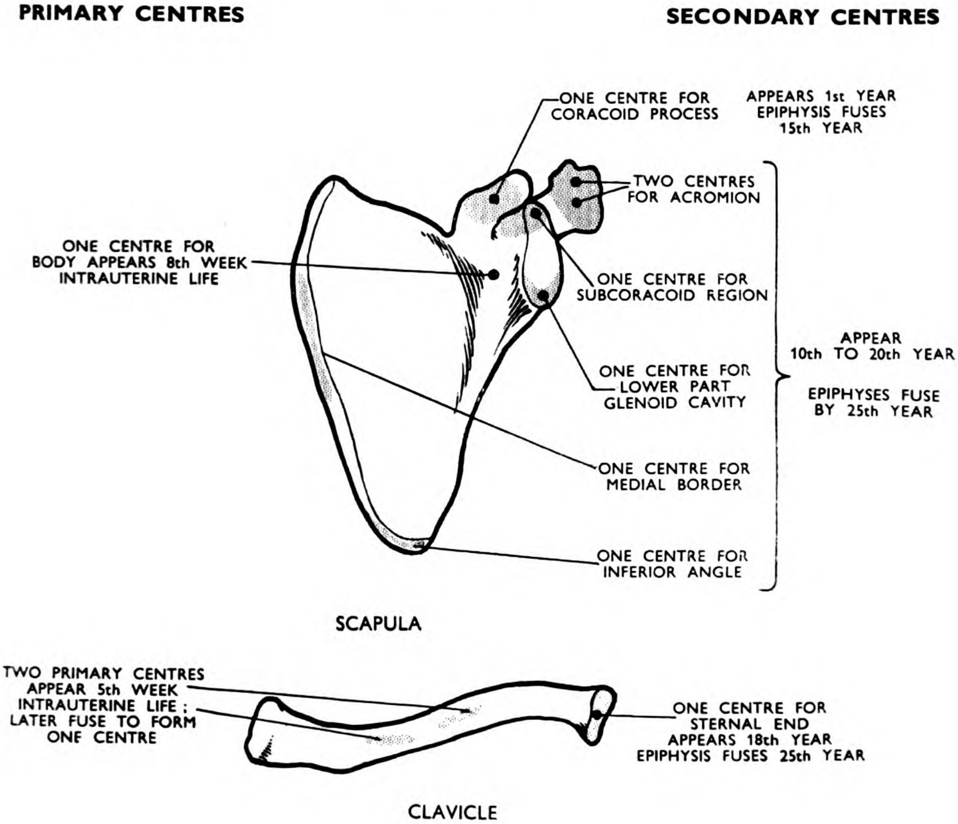


FIG. 46
Ossification of the scapula and clavicle.

FIG. 47
Ossification of the clavicle.

6 MONTHS

FIG. 48A
Ossification at the shoulder joint.

2 YEARS

FIG. 48B
Ossification at the shoulder joint.

18 YEARS

FIG. 48C
Ossification at the shoulder joint.

A series of radiographs (Figs. 48A to 48C) show the bony development of the shoulder joint region.

In Figure 48A at 6 months, the ossification centre for the head of the humerus is just visible, but no secondary centres for the scapula have yet appeared.

In Figure 48B at 2 years, the secondary centre for the greater tuberosity of the humerus is visible and ossification of the head is well advanced.

In Figure 48C at 18 years, the secondary centres for the head and the greater and lesser tuberosities have joined to form one large epiphysis which has not yet united with the shaft. Secondary centres for the acromion and the coracoid process are visible.

CHAPTER III

BONES OF THE LOWER LIMB

THE bones of the lower limb include those of the foot, leg, thigh and hip, with the intervening joints of the foot, ankle, knee and hip (Fig. 49). The hip bones together with the sacrum and coccyx form the pelvis through which the weight of the trunk is transferred to the lower extremities; the bones of the pelvis will be separately described in Chapter IV.

FOOT

The bony structure of the foot is similar in many respects to that of the hand: the differences present mainly result from the fact that the feet support the weight of the trunk and assist in locomotion, whereas the hands are prehensile or capable of grasping. The bony structure of the foot is therefore stronger, but less mobile than that of the hand.

When discussing the foot, it is customary to employ the terms 'dorsal' and 'plantar' in place of 'anterior' and 'posterior': but 'proximal' and 'distal' are also used in the usual sense that the terminal phalanges are the distal bones of the foot.

There are three groups of bones in the foot—the phalanges, the metatarsus and the tarsus (Figs. 50, 51, 52 and 53). They are arranged in a pattern similar to the bones of the hand, but are set in a plane at right angles to the lower leg.

Phalanges

The phalanges of the foot resemble those of the hand. They are similarly arranged in three rows and interarticulate in the same manner. The two phalanges of the great toe, on the medial side of the foot, are relatively large and strong, but those of the other toes are small and short.

Metatarsus

The five metatarsal bones are miniature long bones, similar in structure to the metacarpals. The heads are rounded with slightly flattened sides, and the articular surface extends farther on to the plantar than the dorsal surface. The heads articulate with the concave bases of the proximal phalanges at the metatarso-phalangeal joints. The shafts are prismoid on cross-section and, with the exception of the first metatarsal, are long and slender. The bases articulate with the distal row of tarsal bones; the bases of the second to the fifth metatarsals also articulate with each other.

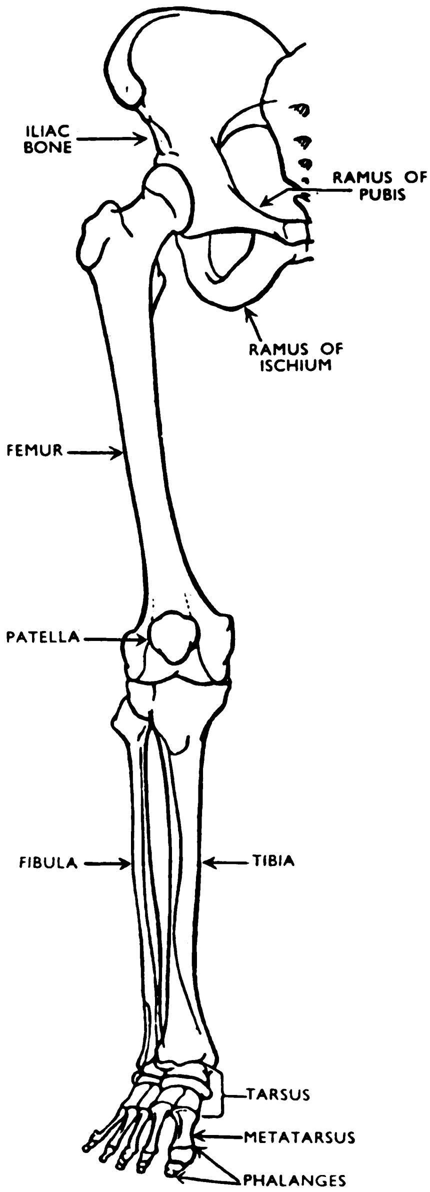


FIG. 49

The bones of the lower limb.
(After Whillis.)

The **first metatarsal bone** is short and thick. The head is large and on its plantar surface are two facets for articulation with the two sesamoid bones which are always present at this site. The sesamoid bones lie side by side: the medial bone is often larger than the lateral, and any one, or both, may consist of two separate fragments.

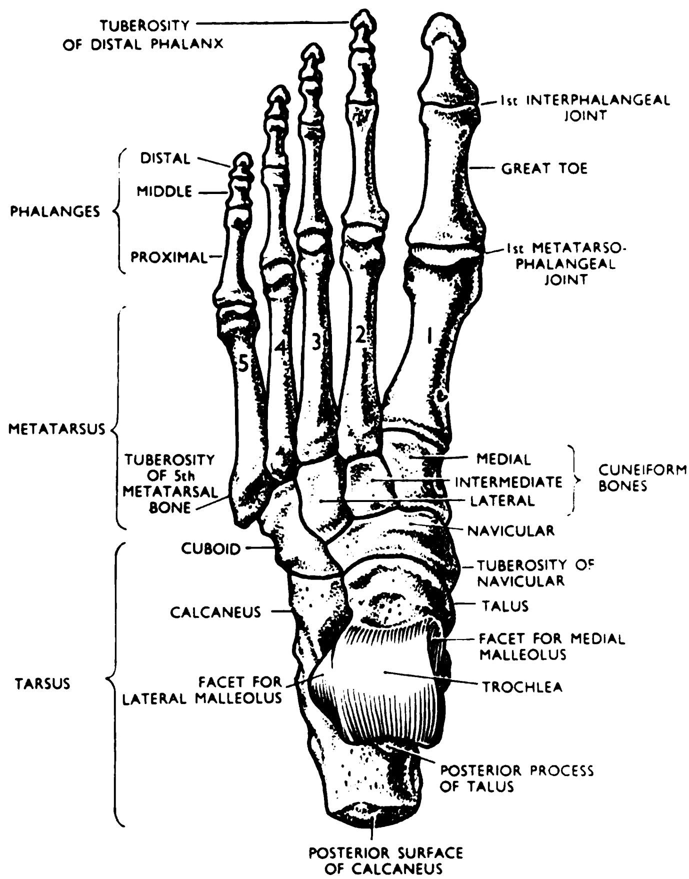


FIG. 50
Left foot: dorsal aspect.

The base of the first metatarsal is large and kidney-shaped and articulates with the medial cuneiform bone of the tarsus.

The **second metatarsal bone** is the longest bone of the metatarsus. Its base is wedge-shaped and extends a short distance proximal to the general line of the metatarso-tarsal joints; it therefore articulates not only with the intermediate cuneiform which directly opposes it, but also with the medial and lateral cuneiforms on either side.

The **third metatarsal bone** articulates proximally with the lateral cuneiform bone.

The **fourth and fifth metatarsal bones** articulate proximally with the cuboid bone. The fifth metatarsal may be distinguished by a tuberosity projecting from the lateral margin of the base.

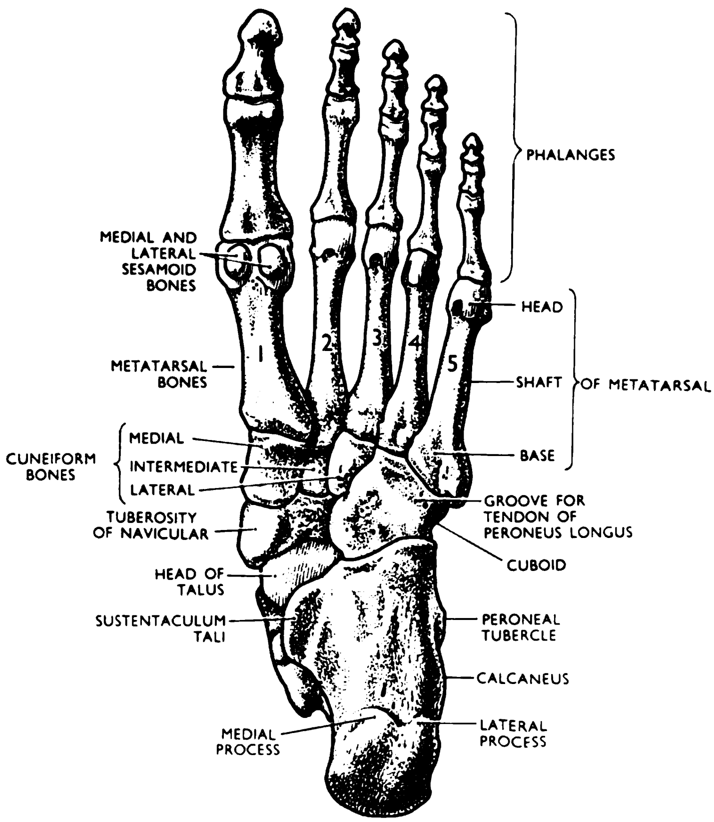


FIG. 51
Left foot: plantar aspect.

Tarsus

There are seven tarsal bones and they are arranged in two rows.

The proximal row consists of two bones, placed one above the other (the talus and calcaneus). The distal row is composed of four bones lying side by side (the three cuneiform bones and the cuboid). One bone (the navicular) is inserted between the two rows.

The upper bone of the proximal row (the talus) articulates with the two bones of the leg (the tibia and fibula) and those of the distal row articulate with the bases of the metatarsals.

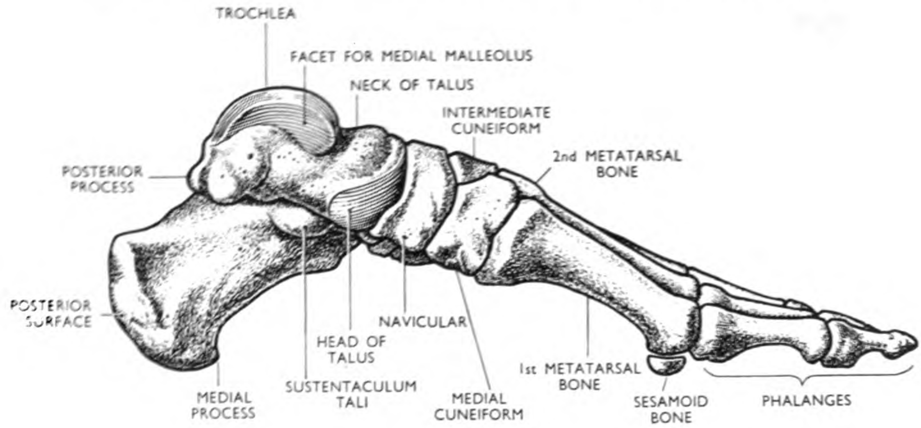


Fig. 52
Left foot: medial aspect.

The names of the tarsal bones (with alternative names in brackets) are :—

Medial side	**Proximal Row**	Above Talus (Astragalus)	Below Calcaneus (Os Calcis)	**Lateral side**
	Inserted between the rows	Navicular (Tarsal Scaphoid)		
	Distal Row	Cuneiforms: Medial (Internal) Intermediate (Middle) Lateral (External)	Cuboid	

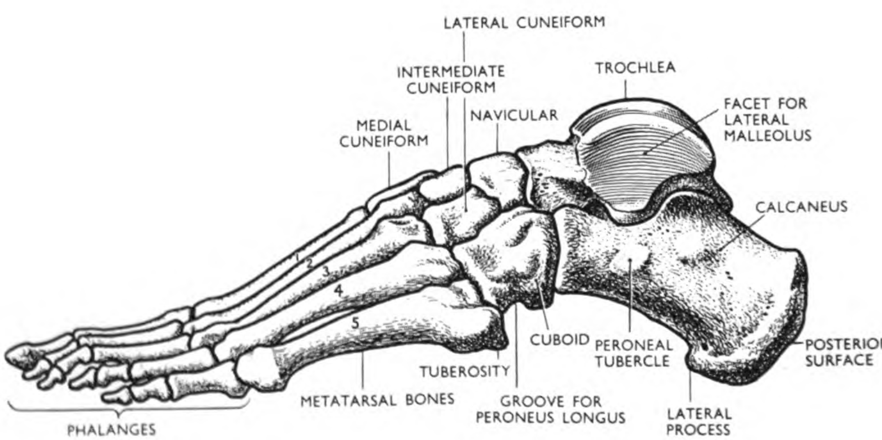


Fig. 53
Left foot: lateral aspect.

Several of the larger bones of the tarsus are important to the radiographer, notably the calcaneus, as their major weight-bearing surfaces are often disrupted in crush fractures.

Talus (Figs. 54, 55 and 56)

The talus is the upper bone of the proximal row of the tarsus and lies over the calcaneus: it forms the ankle joint with the tibia and fibula and provides the connecting link between the leg and the foot.

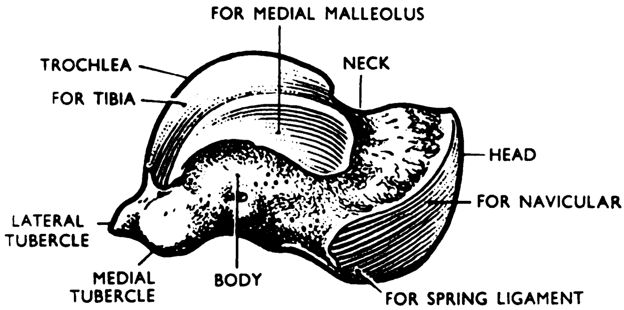


FIG. 54
Left talus: medial aspect.

The talus is divisible into three parts—the body, the neck and the head; the head faces forward.

The **body** is roughly square on cross-section. Its upper or dorsal surface

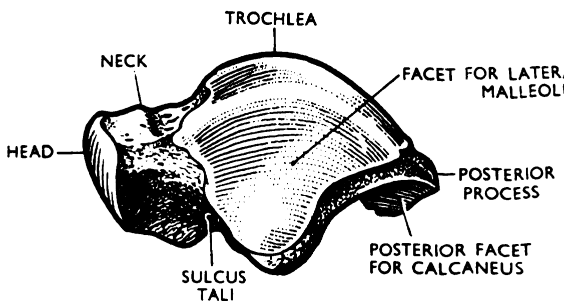


FIG. 55
Left talus: lateral aspect.

is convex from back to front, and is covered with the *trochlear articular surface*, which opposes the lower articular surface of the tibia. This articular surface extends on to the lateral and medial sides of the body, where it articulates with the lateral malleolus of the fibula and the medial malleolus of the tibia. The lateral surface of the body projects downward to an apex, the lateral process of the talus. The lateral articular surface extends almost to the tip of the lateral process and is more extensive than the shallow articular surface

on the medial aspect of the body. The talus, strongly held as it is on both sides by the malleoli, is capable of dorsiflexion and plantar flexion, but lateral and medial movement is strongly resisted by the malleoli and the strong ligaments which surround the ankle joint.

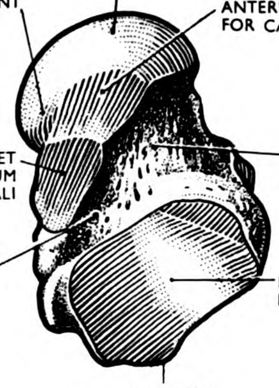


FIG. 56
Left talus: inferior aspect.

FIG. 57
Left talus: lateral radiograph.

Posteriorly, the body narrows to the flat posterior process which is divided by a groove into a medial and a lateral tubercle. Occasionally the posterior process ossifies as a separate bone, when it is known as the os trigonum (Fig. 57).

The **head** at the distal end of the bone is angled slightly downward and medially from the body: it is separated from the body by a short narrower section of bone—the **neck**. The distal surface of the head is convex and articulates with the navicular.

The plantar or inferior surface of the talus articulates with the dorsal or superior surface of the calcaneus through three articular facets, known as the anterior, middle and posterior calcanean articular surfaces. The posterior articular surface is the largest and occupies the whole of the inferior surface of the body; the anterior and middle articular surfaces are smaller and are situated on the inferior surface of the head of the talus; the middle and posterior articular surfaces are therefore separated by the plantar surface of the neck of the talus, and the deep groove between them is known as the sulcus tali.

Calcaneus (Figs. 58, 59 and 60)

The calcaneus is the largest of the tarsal bones and the most important bone in the foot from a radiographic point of view. It is roughly oblong, and in the articulated foot lies below and slightly on the lateral side of the talus,

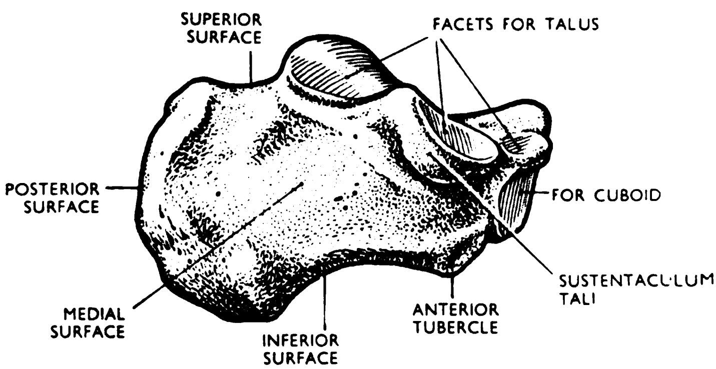


FIG. 58
Left calcaneus: medial aspect.

with its long axis directed forward. The greater and more massive part of the bone lies posterior to the plane of the ankle joint to form a lever for the muscles of the calf.

The posterior surface is large and convex; the tendo calcaneus (tendo achillis) of the calf muscles is inserted into the roughened middle third of the posterior surface and is separated from the smooth upper third by a bursa. The anterior surface is relatively small and articulates with the cuboid. The medial surface is slightly concave, but an important shelf of bone, the sustentaculum tali, projects medially from the antero-superior part of this surface and supports the head of the talus. The lateral surface is flat except for the small peroneal tubercle which projects between the tendons of the peroneal muscles.

The upper or dorsal surface presents three articular facets toward the front of the bone, corresponding to the anterior, middle and posterior facets

of the talus. The posterior facet is the largest; it is convex and articulates with the posterior facet on the under aspect of the talus, forming the posterior talo-calcanean or subtalar joint. The anterior and middle facets are small

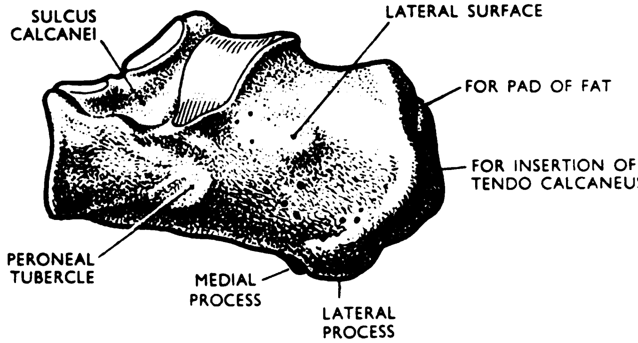


FIG. 59
Left calcaneus: lateral aspect.

and are situated on the medial part of the upper surface of the bone; the middle facet lies on the upper surface of the sustentaculum tali, and a deep groove (the sulcus calcanei) separates it from the posterior facet. When the

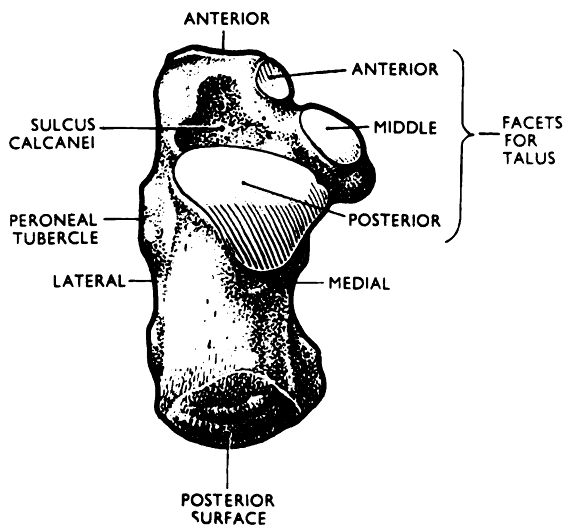


FIG. 60
Left calcaneus: superior aspect.

talus and the calcaneus are articulated, the sulcus calcanei and the corresponding sulcus tali form an oblique tunnel, the sinus tarsi, in which lies a strong interosseous ligament joining the bones.

The plantar surface of the calcaneus is slightly concave. At its posterior end is the calcanean tuberosity, divided by a shallow groove into a medial and a lateral process; the long plantar ligament is attached to the bone

immediately in front of this tuberosity. Near the anterior end of the plantar surface is a rounded protuberance, the anterior tubercle, to which the short plantar ligament is attached.

Navicular (Figs. 50 and 52)

The navicular is roughly disc-shaped and is situated on the medial side of the foot. It lies between the proximal and distal rows of tarsal bones. The proximal surface is concave and articulates with the head of the talus. The distal surface is convex and is divided into three facets which articulate with the three cuneiform bones. A well-marked bony tuberosity projects downward and backward from the medial surface and receives the principal insertion of the tibialis posterior tendon.

Cuneiform Bones (Figs. 50 and 51)

These three small bones lie side by side on the medial side of the distal row of the tarsus: the medial cuneiform is the largest and the intermediate the smallest. They articulate proximally with the navicular and distally with the medial three metatarsals. They are wedge-shaped and form part of the transverse arch of the foot.

Cuboid (Figs. 50, 51 and 53)

The cuboid lies on the lateral side of the distal row of the tarsus. It is a flattened six-sided bone. It articulates proximally with the calcaneus, distally with the fourth and fifth metatarsals, and medially with the lateral cuneiform. A deep oblique groove for the tendon of the peroneus longus begins on the lateral surface of the bone and extends on to the plantar surface where it is bounded behind by a prominent oblique ridge. Frequently the tendon of the peroneus longus contains a sesamoid bone, which articulates with the lateral side of the cuboid (Fig. 61).

Arches of the Foot

The bones of the foot form a number of springy arches which transfer the weight of the body to the ground without shock, this being achieved by the shape of the bones, the connecting ligaments, the small muscles of the sole and the sling action of some of the long tendons of the leg muscles. These factors convert the foot into a resilient lever which propels the body in walking, running or jumping.

There are two arches—longitudinal and transverse. The longitudinal arch rests behind on the tuberosity of the calcaneus and in front on the heads of the metatarsals (Fig. 52). This arch is highest on the medial side of the foot where the talus forms the apex or keystone. The transverse arch is complete at the level of the bases of the metatarsals, but in the midtarsal region only half an arch is present, and to complete this arch the two feet must be placed together.

One of the important ligaments maintaining the longitudinal arch is the plantar calcaneo-navicular or spring ligament: this is attached distally to the navicular and proximally to the sustentaculum tali and supports the head of the talus. Another important ligament is the long plantar ligament which extends from the under surface of the calcaneus to the ridge on the cuboid and also to the bases of the second, third and fourth metatarsals.

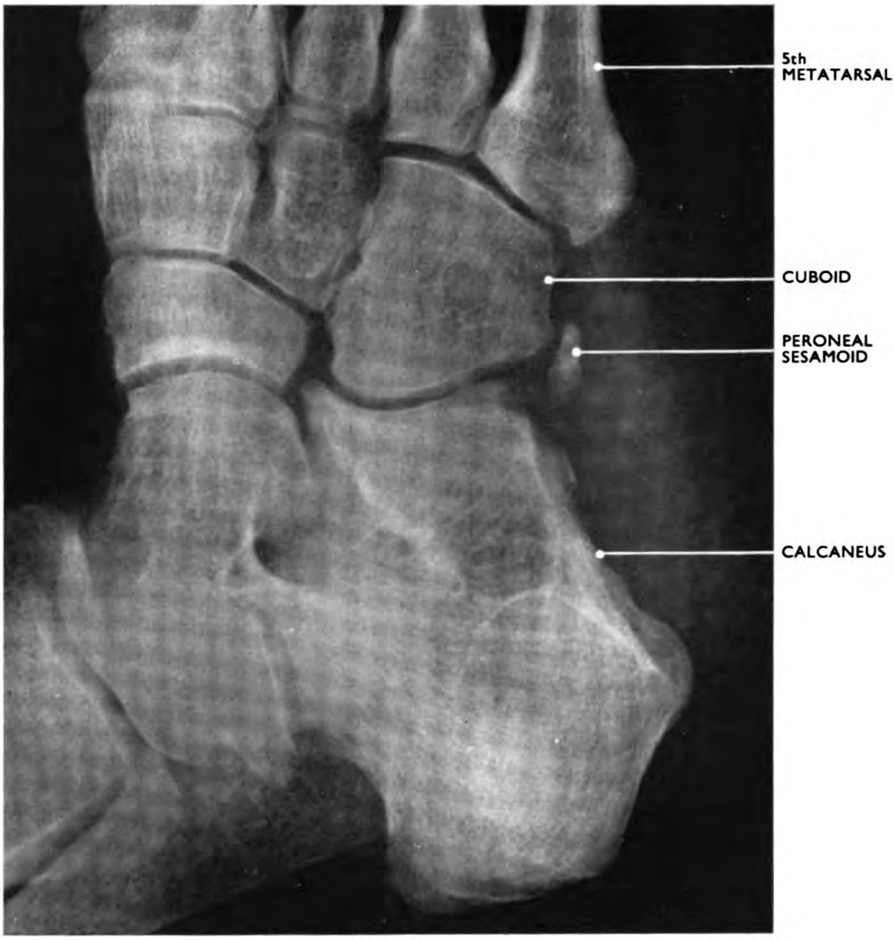


FIG. 61
Right foot: dorsi-plantar oblique radiograph to show peroneal sesamoid.

RADIOGRAPHIC APPEARANCES OF THE FOOT

Foot: Dorsi-plantar Radiograph (Fig. 62)

This radiograph is taken with the X-ray tube centred directly over the foot, which has been placed ' flat ' on the film. It is principally of value in the examination of the forefoot, especially the great toe.

FIG. 62
Left foot: dorsi-plantar radiograph.

The number and general configuration of the metatarsal bones, phalanges and intervening joints correspond to the metacarpal bones, phalanges and joints of the hand. Thus there are three phalanges to each toe, with the exception of the big toe, which has only two.

The **phalanges** of the foot are, however, relatively smaller than those of the hand. Shoe pressure tends to crowd them together, and also to fold those of the smaller toes downward so that they appear foreshortened in this radiographic view. It is not uncommon for the distal and middle phalanges of the little toe to be fused, with consequent obliteration of the interphalangeal joints.

The **first metatarsal** bone is seen to be considerably thicker and a little shorter than the other metatarsals. Its head has a convex articular surface which extends farther on to the plantar surface than the dorsal surface, a feature common to all metatarsals. The head partly overshadows two sesamoid bones, which are always present on its plantar surface; it is not uncommon to find one or other of these sesamoids divided into two parts, as in Figure 63. The base of the bone is clearly visible in this view (Fig. 62): it articulates only with the medial cuneiform bone of the tarsus.

The shafts of the second to fifth metatarsal bones are long and slender: their bases overlap slightly and the intermetatarsal joints are not clearly demonstrated.

The individual tarsal bones cannot be easily distinguished, since the joint spaces are also obscured by overlap. The reason lies in the fact that the plane of the bones of the foot distal to the talus slopes downward and outward, and the joint spaces are therefore oblique to the rays when the X-ray tube is centred directly above.

The talus and the posterior part of the calcaneus are obscured by the superimposed shadows of the tibia and fibula.

Foot : Dorsi-plantar Oblique Radiograph (Fig. 63)

If the X-ray tube is directed slightly medially and backward so that the central ray is at right angles to the plane of the anterior part of the foot, the resultant radiograph will provide a good demonstration of the tarsus and metatarsus, since most of the joint spaces are now visible. Slight inclination of the leg medially, *i.e.*, away from the side of the X-ray tube, will also assist by projecting the shadows of the tibia and fibula clear of the posterior part of the foot.

The radiographic appearances of the phalanges and metatarsals are similar to those seen in the dorsi-plantar radiograph. Owing to the oblique angulation of the X-ray tube, the base of the first metatarsal is, however, partly overshadowed by that of the second metatarsal, although the bases of the other metatarsals are now clearly visible. The second metatarsal is seen to be the longest and the first metatarsal the shortest. The tuberosity on the outer margin of the base of the fifth metatarsal is well demonstrated and is a common site of fracture.

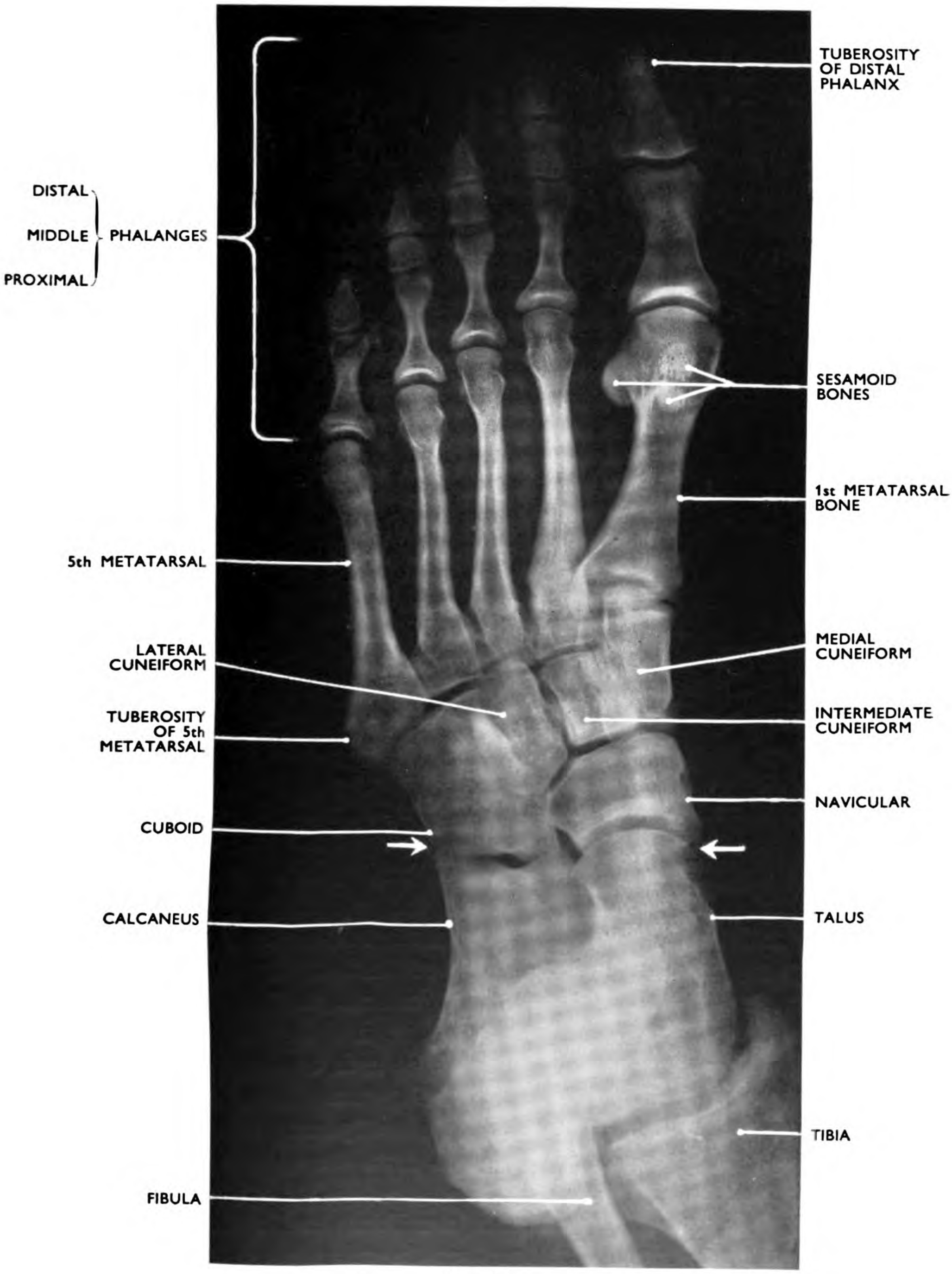


FIG. 63
Left foot: dorsi-plantar oblique radiograph.
(Arrows mark the transverse midtarsal joint.)

The shadows of the distal row of tarsal bones overlap slightly, but the shape of the individual bones is recognisable.

The three cuneiform bones on the medial side of the distal tarsal row appear roughly oblong. Distally they each articulate with the base of a metatarsal bone (metatarsals 1 to 3) and proximally they all articulate with the navicular bone, as well as with each other. The intermediate cuneiform is smaller than the other cuneiforms so that the second metatarso-tarsal joint is set back from the general line of the metatarso-tarsal joints.

Whilst the distal articular surface of the navicular has three facets for the three cuneiform bones, its proximal surface is uniformly concave to accommodate the convex head of the talus.

The irregular six-sided cuboid on the lateral side of the distal tarsal row is seen to articulate distally with the bases of the fourth and fifth metatarsals, proximally with the calcaneus, and medially with the lateral cuneiform.

The joints between the navicular and talus on the medial side and the cuboid and calcaneus on the lateral side of the foot form the transverse midtarsal joint shown by the arrows in Figures 63 and 65: it is at this transverse joint that movements of inversion and eversion of the foot take place.

The articulations between the talus and calcaneus are obscured by overlap of the bones in this radiographic view and are more adequately demonstrated in the oblique radiograph and special calcanean radiographic views.

Foot : Lateral Radiograph (Fig. 64)

The lateral radiograph demonstrates the structure and shape of the longitudinal arch of the foot.

The talus is seen to form the apex of the arch, which has a short posterior segment composed only of the calcaneus, and a relatively long anterior segment, comprising the navicular, cuneiforms, cuboid and metatarsal bones.

The medial part of the longitudinal arch (calcaneus, talus, navicular, cuneiforms, and first, second and third metatarsals) is noticeably higher than the lateral part (calcaneus, cuboid, and fourth and fifth metatarsals).

Of the soft tissue structures—muscle, muscle tendons and ligaments—which help to maintain the arch, only the plantar ligaments can be identified. The long plantar ligament at the base of the arch extends from the plantar surface of the calcaneus to the bases of the metatarsals and is nearly always faintly outlined. Occasionally the short plantar ligament near the apex of the arch is also partially visible: this extends from the anterior tubercle of the calcaneus to the cuboid.

The bony features of the metatarsals, cuneiforms and cuboid are not clearly identifiable owing to superimposition, but the calcaneus, talus and navicular bones stand out clearly.

The head of the talus, separated from the body by the slightly narrowed neck, articulates distally with the disc-shaped navicular bone.

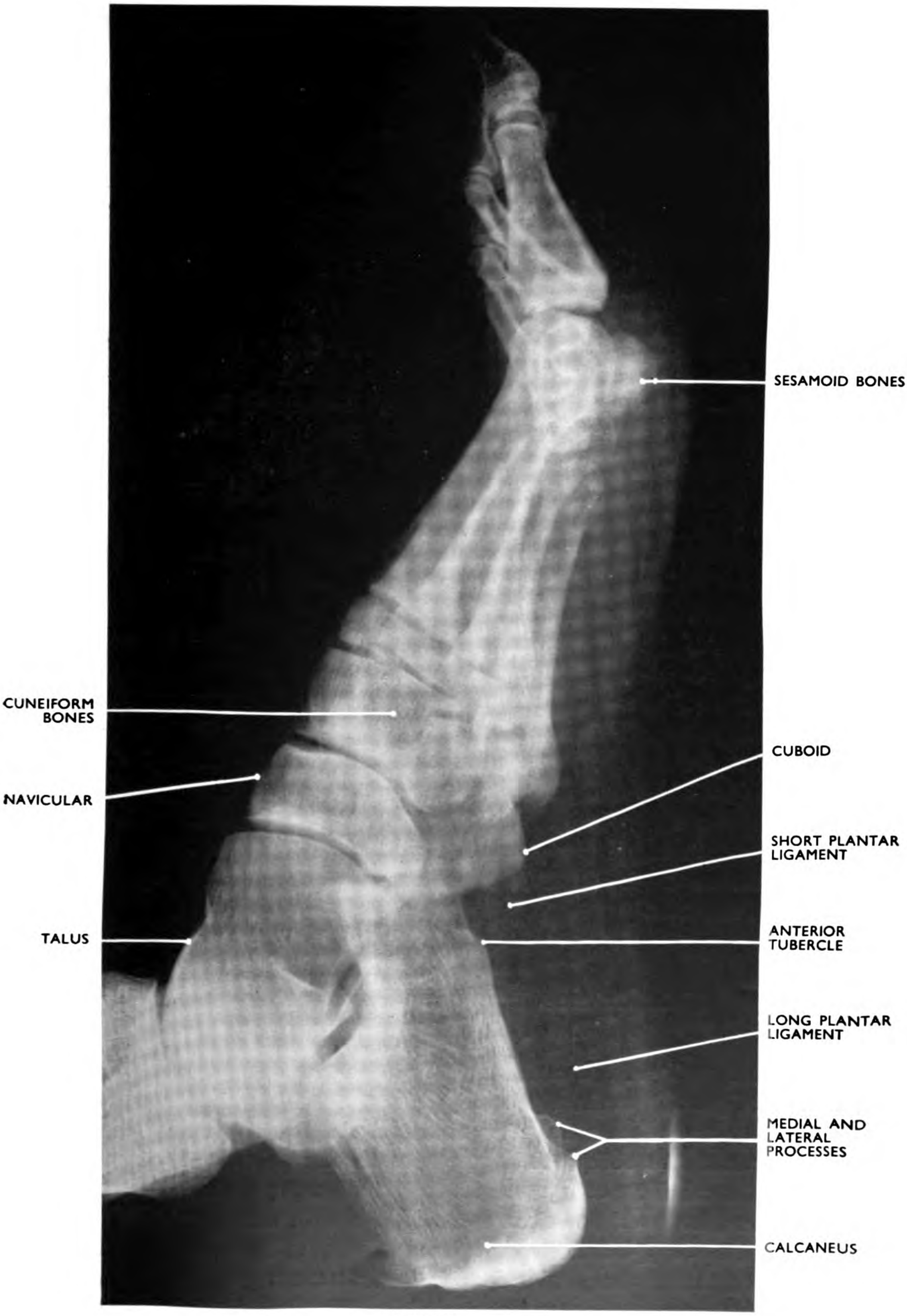


FIG. 64
Left foot: lateral radiograph.

The convex trochlear articular surface on the upper part of the body of the talus is clearly seen in profile, whilst on the plantar surface of the body the posterior articular surface for the calcaneus can be identified.

The anterior and middle articular facets between the talus and calcaneus are not well demonstrated, since the joint spaces are oblique to the X-ray beam, and the facets are partly overshadowed by the tongue-like lateral process of the talus.

Foot : Oblique Radiograph (Fig. 65)

The oblique radiograph is taken with the lateral side of the foot in contact with the film and the sole of the foot at 45° to the film surface. The view so obtained is a more valuable complementary projection to the dorsi-plantar views than the lateral radiograph, as there is less superimposition of individual bones. In particular, separation of the shadows of the metatarsal bones is adequate to check possible injuries which may only be suspected on the dorsi-plantar views.

The cuboid is well demonstrated and the bony ridge on its plantar surface is seen to cross the bone obliquely to end in a tuberosity: in front of the ridge is the groove for the tendon of the peroneus longus muscle.

The tuberosity of the navicular is seen to project backward, partly overshadowing the head of the talus.

The appearance of the calcaneus is similar to that seen in the lateral radiograph, but a good view is now obtained of the three articular facets present between the talus and calcaneus. The anterior facet lies near the beaked upper distal margin of the calcaneus: behind and separated by a clear space is a slightly elevated shelf of bone, the sustentaculum tali, on which the middle articular facet is situated. Since the posterior articular facet is a curved surface, only part of it is clearly seen, overshadowed by the lateral process of the talus.

Radiographic Examination of the Calcaneus and Talo-calcanean Joints

Detailed radiographic examination of the calcaneus and talo-calcanean joints is of great importance, since injuries in this region may seriously affect the stability of the foot as a whole and they are not always easily detected.

The lateral and oblique radiographs of the foot provide slightly differing views of the calcaneus at right angles to its long axis; the talo-calcanean joint surfaces are, however, not clearly visible. As with other important bones it is essential that supplementary views be obtained; in the case of the calcaneus, views in or near the long axis of the bone are necessary and three such views are usually taken.

FIG. 65
Left foot: oblique radiograph.

Calcaneus : Axial Radiograph (Fig. 66)

The axial radiograph is taken with the subject standing with both feet together: the X-ray tube is directed downward and inward at 30° from the vertical to centre between the heels.

This view shows the posterior part of the calcaneus, with the medial and

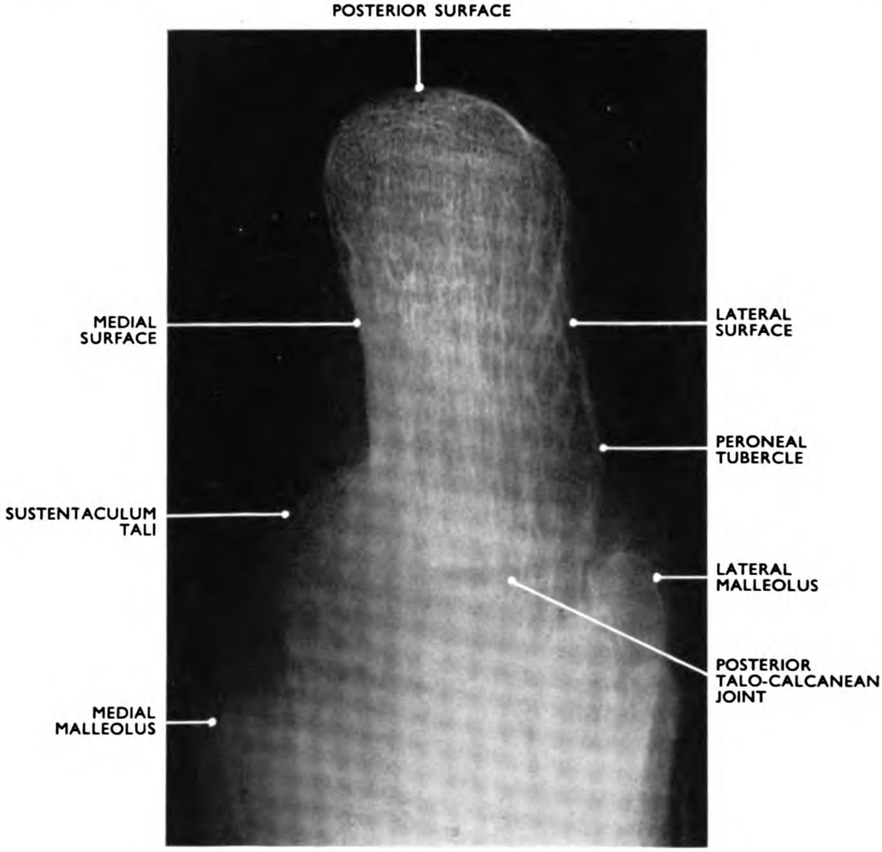


FIG. 66
Left calcaneus : axial radiograph.

lateral surfaces in profile. The shelf-like projection of the sustentaculum tali is clearly visible on the medial surface, and on the lateral surface is the small projection of the peroneal tubercle. The posterior talo-calcanean joint is visible as a double line extending across the bone at the level of the sustentaculum tali, but as this joint surface is curved, only the anterior lip of the joint is distinct. At the same level, the lateral malleolus is seen as an elongated shadow on the lateral side of the calcaneus, whilst the medial malleolus lies at a higher level on the medial side.

Talo-calcanean Joints

Two oblique radiographs are of considerable value in the examination of the joints between the talus and the calcaneus.

1. **Oblique-medial Radiograph** (Fig. 67). With the patient sitting, the foot

FIG. 67
Left talo-calcanean joint: oblique-medial radiograph.

is flexed at the ankle joint and the leg rotated medially to 45°: the central ray is then directed upward at 20° toward the lateral malleolus.

In the radiograph a squat image of the talus and a foreshortened picture of the calcaneus is obtained. The middle third of the curved posterior talo-calcanean joint is clearly visible, as is the middle talo-calcanean joint situated on the sustentaculum tali.

Variations of the upward tilt from 40° to 10° can be made for a series of films to show the whole of the surface of the posterior talo-calcanean joint from front to back respectively.

2. **Oblique-lateral Radiograph** (Fig. 68). With the foot still flexed at the

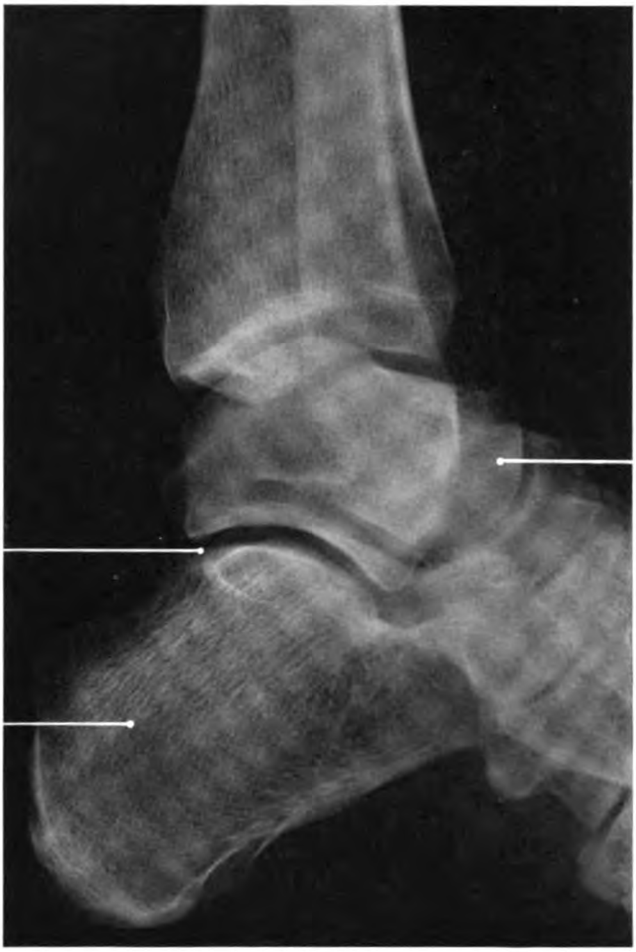
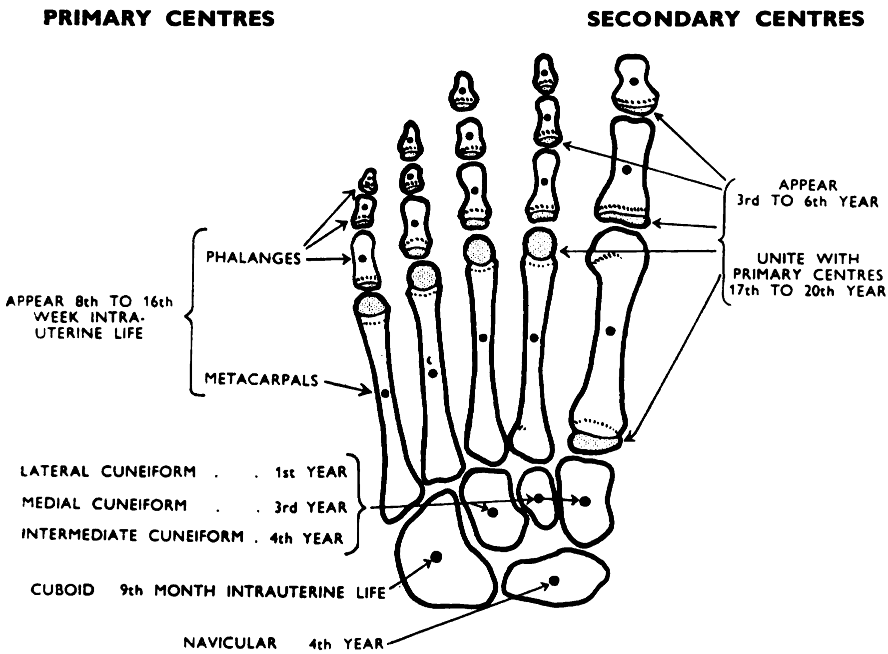


FIG. 68
Left talo-calcanean joint: oblique-lateral radiograph.

ankle joint, the leg is rotated laterally to 45°: the X-ray tube is tilted upward at 15° toward the medial malleolus. This radiograph shows a clear lateral view of the posterior talo-calcanean joint.

Ossification of the Bones of the Foot (Fig. 69)

It will be seen in the radiograph of the newborn child (Fig. 3) that ossification of the bones of the foot commences before birth, as is also the case in the bones of the hand.



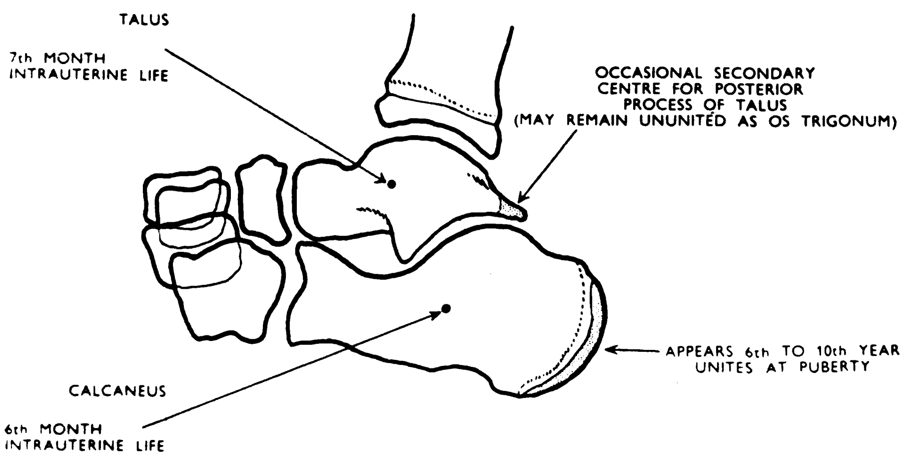


FIG. 69
Diagram of the ossification of the foot.

The general pattern of ossification in the foot is similar to that of the hand. Thus, each **metatarsal and phalanx** ossifies from one primary and one secondary centre.

The primary centres appear in the shafts of the metatarsals and phalanges between the eighth and sixteenth weeks of intrauterine life.

3 YEARS

FIG. 70A

Ossification of the bones of the foot.

The secondary centres for the phalanges develop at the base of each bone between the third and sixth year.

As in the hand, the secondary centre for the first metatarsal is present at the base of the bone, and at the head of the second to the fifth metatarsals. Occasionally a small epiphysis is present for the tuberosity at the base of the fifth metatarsal (Fig. 70C): this has been mistaken for a fracture.

Fusion of the epiphyses and the shafts of the phalanges and metatarsals takes place between the seventeenth and twentieth years.

The **tarsal bones** each ossify from one primary centre. A thin scale-like secondary centre for the extreme posterior part of the calcaneus is, however,

always present. Occasionally the posterior process of the talus ossifies from a small additional centre: this centre may fail to unite with the main body of the bone and persist as a separate ossicle, the os trigonum (Fig. 57), and should not be mistaken for a fracture.

Whereas, at birth, no ossification centres are visible in the carpus,

7 YEARS

FIG. 70B

Ossification of the bones of the foot.

three tarsal bones (the calcaneus, talus and cuboid) are already partly ossified.

A series of radiographs (Fig. 70A to 70C) show the gradual development of the bones of the foot.

12 YEARS
FIG. 70C
Ossification of the bones of the foot.

BONES OF THE LEG

The two long bones of the leg, the tibia and the fibula, lie side by side, and articulate only at their upper and lower extremities. The tibia, which is much the stouter and stronger bone, lies on the medial side and the fibula on the lateral side of the leg.

Tibia (Fig. 71)

This stout bone consists of a large upper end joined by a long shaft to a smaller lower end. The tibia articulates with the femur at the knee joint and with the talus at the ankle joint.

The expanded **Upper End** of the tibia is wide from side to side, but also overhangs the shaft posteriorly. It consists of medial and lateral condyles which supply the weight-bearing surfaces of the knee joint. On the superior surface of each condyle is an articular surface for articulation with the corresponding condyle of the femur. Between the articular surfaces is a narrow, slightly irregular non-articular space, the intercondylar area, upon which is situated the intercondylar eminence.

The **medial condyle** is the larger of the two condyles, although its projection over the shaft of the bone is less marked than that of the lateral condyle. The articular area on its superior surface is oval and is also gently concave: this concavity is accentuated laterally by the medial intercondylar tubercle, one of the two tubercles of the intercondylar eminence. The anterior and medial surfaces of the condyle are rough: a horizontal groove is present on the posterior surface just below the articular margin.

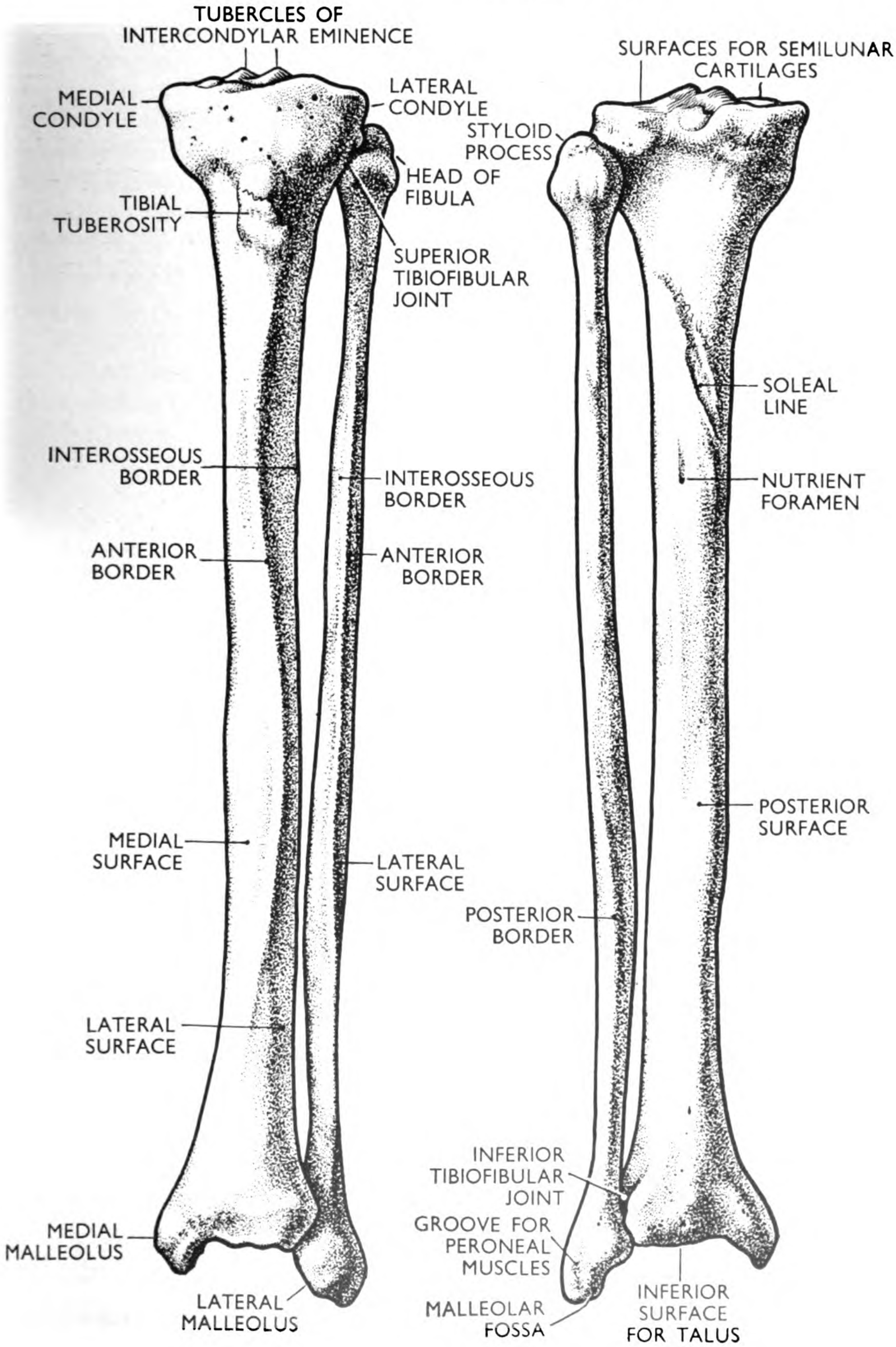


FIG. 71
Left tibia and fibula: anterior and posterior aspects.

The **lateral condyle** overhangs the shaft, particularly postero-laterally where a small articular facet is present for articulation with the head of the fibula at the superior tibiofibular joint.

The articular area on the superior surface is smaller than that on the medial condyle: it is nearly circular in shape, gently concave, and extends on its medial side to the lateral intercondylar tubercle. The anterior, posterior and lateral surfaces of the condyle are rough.

The **semilunar cartilages (menisci)** (Fig. 72) serve to deepen the concavity of the tibial condyles and to adapt their superior surfaces to the rounded femoral

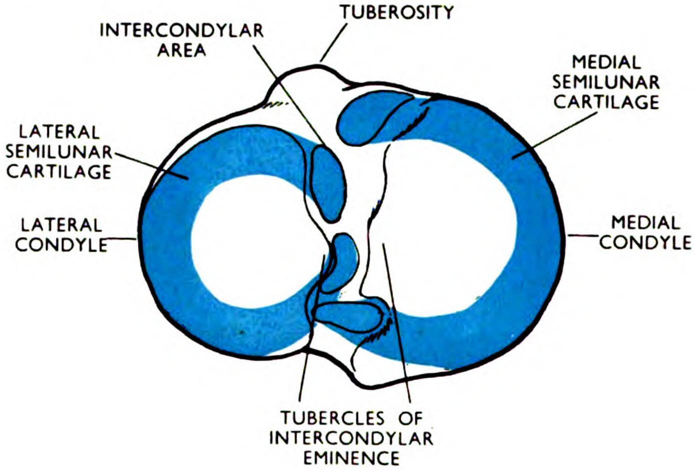


FIG. 72
Diagram of upper surface of tibia and semilunar cartilages.

condyles. They are crescentic in shape and lie on the outer margins of the condyles, but do not cover the whole upper surface of the condyles. The anterior and posterior horns of each crescent face toward the intercondylar area, to which they are attached by fibrous extensions. On cross-section the menisci are wedge-shaped with the thicker outer margin attached to the underlying bone and to the capsular ligaments of the knee joint by short fibres.

The **medial semilunar cartilage** is broader behind than in front and is nearly semicircular in shape. At its outer edge it is attached to the tibial collateral ligament of the knee joint.

The **lateral semilunar cartilage** is almost circular and covers more of the articular surface than the medial cartilage. It is separated from the fibular collateral ligament on the lateral side of the knee joint by the tendon of the popliteus muscle.

The **tuberosity of the tibia** (tibial tubercle) is a low bony projection on the anterior surface of the upper end of the bone, about an inch below the superior margin of the condyles: it is easily felt through the skin.

The ligamentum patellæ is inserted into the upper part of this tuberosity: this ligament is the final tendon of the quadriceps femoris, the large extensor

muscle of the thigh, and in which the patella is situated higher up at the level of the femoral condyles.

The Shaft of the tibia is prismoid on cross-section. It has three borders—anterior, medial and interosseous—which separate three surfaces, medial, lateral and posterior.

The curved anterior border begins below the tuberosity of the tibia and extends to the anterior border of the medial malleolus. It is easily felt as it is subcutaneous throughout and forms the crest of the shin.

The medial border begins below the groove on the medial condyle and ends on the posterior surface of the medial malleolus.

The interosseous border gives attachment to the interosseous membrane, connecting the tibia to the fibula: it extends from in front of the fibular facet downward to the fibular notch on the lower end of the tibia.

The medial surface is smooth and subcutaneous for most of its length.

The lateral surface is twisted, due to the curved anterior border: superiorly it is situated on the lateral aspect of the shaft, but inferiorly it twists to extend on to the anterior aspect.

The upper end of the posterior surface is crossed obliquely by a ridge of bone, the soleal line, which gives attachment to some fibres of the soleus muscle of the calf.

The enlarged **Lower End of the Tibia** presents five surfaces. The anterior and posterior surfaces are convex: a groove for the tendon of the tibialis posterior muscle is present on the posterior surface.

The medial surface is prolonged downward as the **medial malleolus,** which articulates with the medial side of the body of the talus.

The **fibular notch** forms the lateral surface. The lower end of the fibula fits into this notch and is attached to the tibia by a strong interosseous ligament forming the inferior tibiofibular joint.

The inferior surface consists of an almost square articular facet, slightly broader anteriorly than posteriorly. It is concave from back to front and a little convex from side to side to conform to the trochlear articular surface of the talus with which it articulates at the ankle joint.

The presence of the tuberosity and well-defined anterior border of the shaft with the prominent medial malleolus serve to identify an individual tibia as belonging to the right or left side of the body.

Fibula (Fig. 71)

The fibula lies on the lateral side of the tibia. It is a long thin bone and is not constructed to take any share in supporting the weight of the body: it does not take part in the knee joint, but its lower extremity, the lateral malleolus, forms an important part of the ankle joint.

The fibula consists of a head, a shaft and a lower end (the lateral malleolus).

The Head is small and bears on its upper surface a facet for articulation with the lateral condyle of the tibia at the superior tibiofibular joint. This

joint is situated on the postero-lateral surface of the lateral condyle and the head of the fibula can be felt about an inch below the level of the knee joint.

The styloid process projects upward from the posterior surface of the head. The peroneus longus muscle on the lateral aspect of the leg is attached to the head and upper shaft of the fibula. Immediately below the head is the neck of the fibula; this is important to radiographers since fractures of the ankle joint often include a fracture of the neck of the fibula.

The Shaft is triangular on cross-section and has anterior, posterior and lateral surfaces separated by well-marked borders. The border separating the anterior and posterior surfaces is called the interosseous border and gives attachment to the interosseous membrane which connects the tibia and fibula through most of their length.

The lower part of the shaft fits into the fibular notch on the lateral surface of the tibia.

The Lower End of the fibula projects downward and is slightly expanded to form the lateral malleolus: it descends about half an inch lower than the medial malleolus of the tibia. On the medial surface of the lateral malleolus is a triangular facet for articulation with the lateral surface of the talus. Behind the facet there is a small depression, the malleolar fossa, to which part of the lateral ligament of the ankle joint is attached. A well-marked groove for the tendons of the peroneal muscles is present on the posterior aspect of the lateral malleolus.

RADIOGRAPHIC APPEARANCES OF THE LEG

Tibia and Fibula : Antero-posterior Radiograph (Fig. 73)

The expanded upper end of the tibia is seen articulating with the femur at the knee joint. The slightly concave articular surfaces of the tibial condyles are visible, as well as the intercondylar tubercles.

The lateral condyle of the tibia partly overshadows the head of the fibula and the styloid process, due to the postero-lateral position of the superior tibiofibular joint. The neck of the fibula is, however, free from superimposed shadows. The tibial tuberosity is seen as an area of increased bone density below the intercondylar tubercles, but is best seen in profile on the lateral radiograph.

Separation of the shafts of the tibia and fibula is seen to be greatest in the upper part of the leg: the interosseous membrane does not cast a shadow. The medullary cavities of both bones can be identified: it will be noticed that the cortical bone is thickest in the midshaft region and thinnest near the articular ends where the spongy or trabecular bone is most pronounced. In this particular radiograph a thin line of increased bone density near the ends of the bones marks the site of fusion of the primary and secondary centres of ossification (the epiphyseal scar).

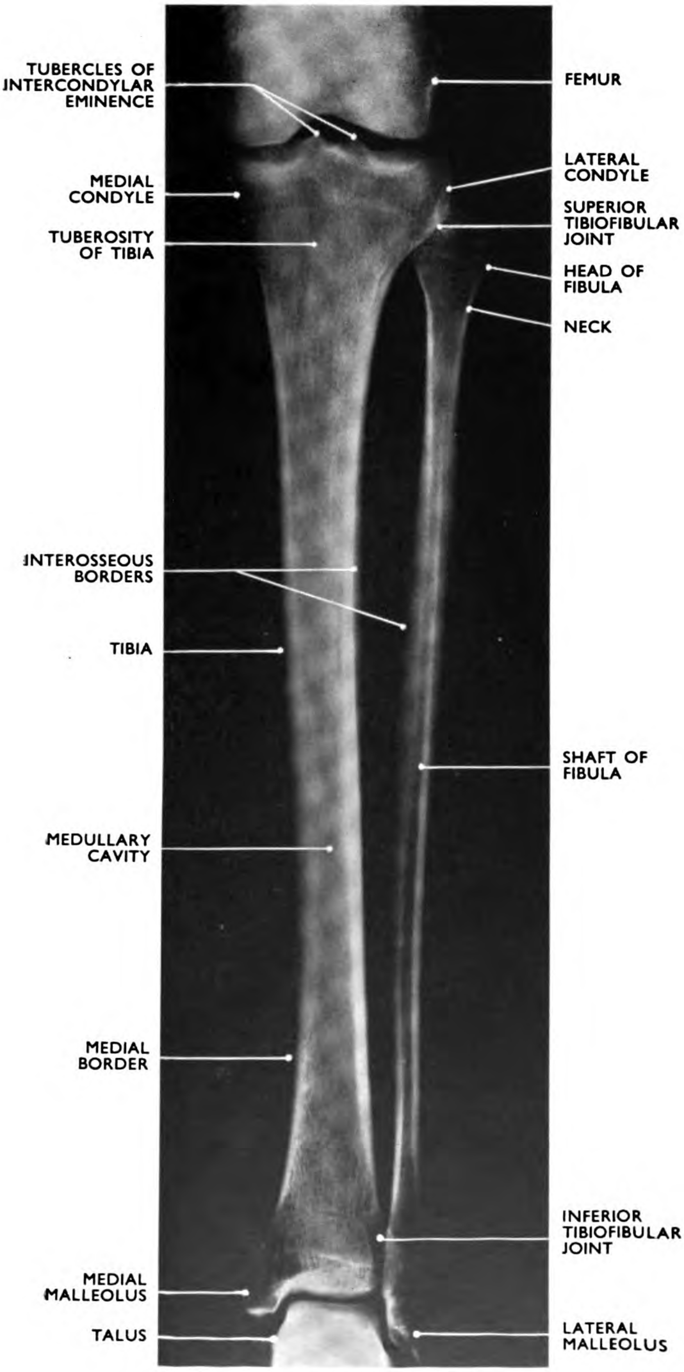


FIG. 73

Left tibia and fibula: antero-posterior radiograph.

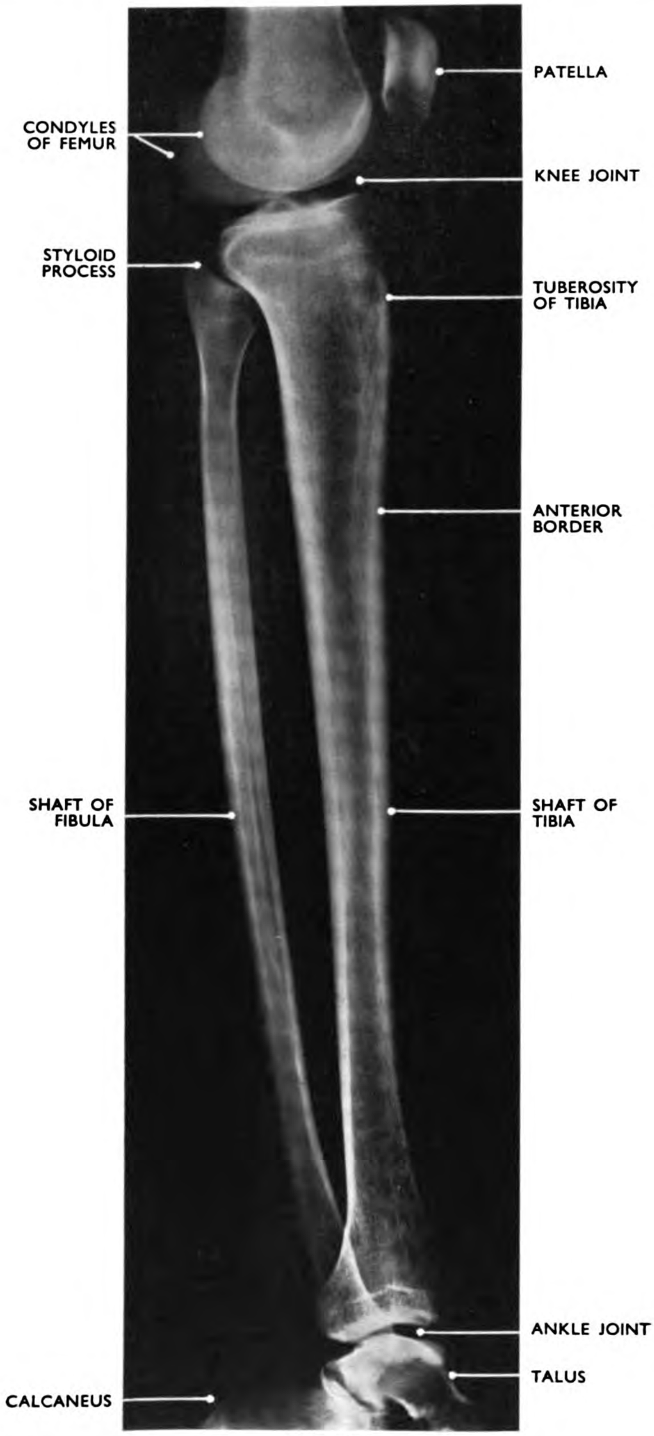


FIG. 74
Left tibia and fibula: lateral radiograph.

Tibia and Fibula : Lateral Radiograph (Fig. 74)

In this projection the tibial condyles are superimposed, but the posterior overhang is clearly visible. The head and styloid process of the fibula are almost clear of superimposed shadows, whilst the tibial tuberosity is clearly seen on the anterior surface of the tibia. It will be appreciated from this radiograph that the fibula lies slightly posterior to the tibia throughout most of its length, only approaching at the inferior tibiofibular joint. The fibula is also slightly bowed, with the convexity directed posteriorly.

Superior Tibiofibular Joint : Oblique Radiograph (Fig. 75)

Since the superior tibiofibular joint is situated on the postero-lateral surface of the lateral tibial condyle, a clear profile view of the joint can only be achieved by taking a radiograph with the leg in medial rotation. The styloid process is also clearly demonstrated.

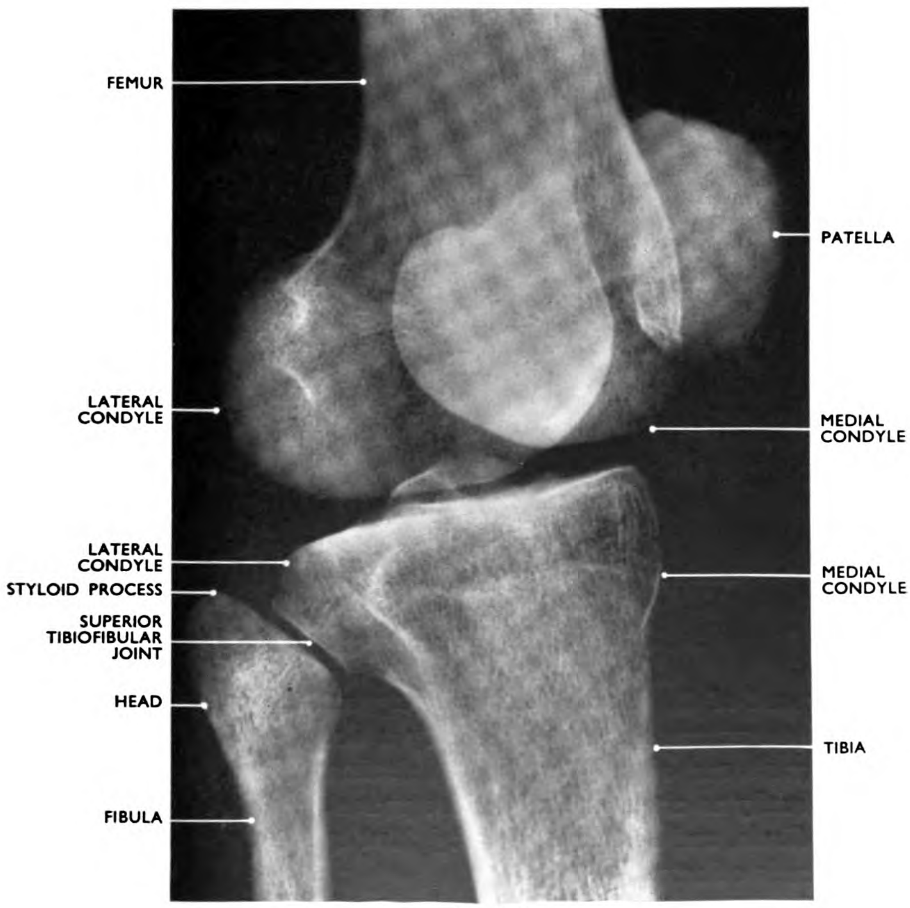


Fig. 75
Left superior tibiofibular joint : oblique radiograph

Ankle Joint : Antero-posterior Radiograph (Fig. 76)

At the line of the ankle joint, the inferior surface of the tibia fits neatly over the trochlea of the talus, with the short medial malleolus and the longer lateral malleolus projecting downward on either side.

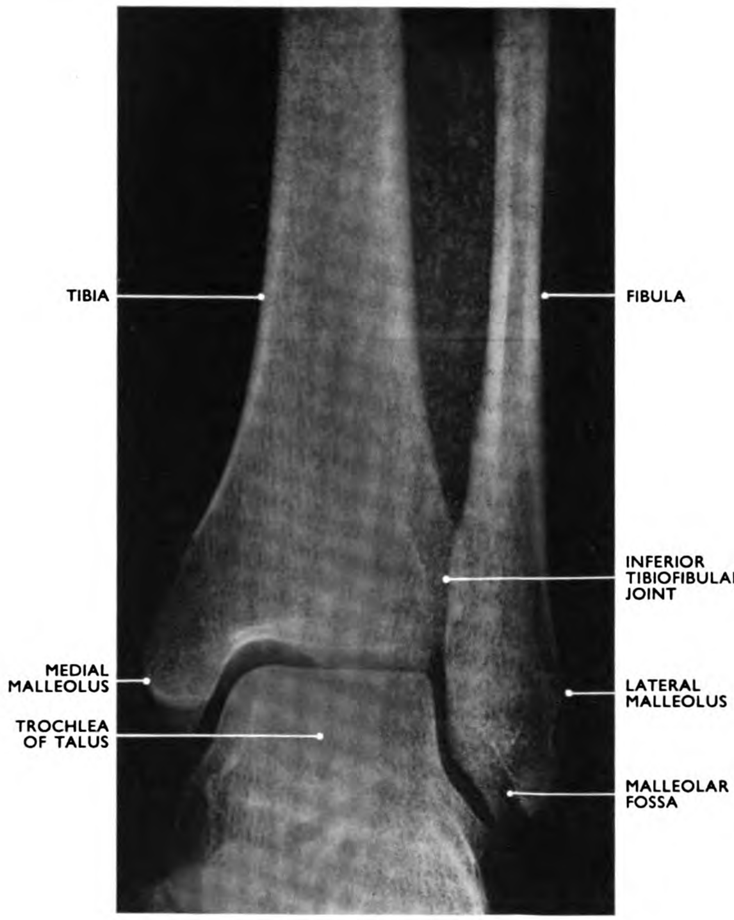


FIG. 76
Left ankle joint : antero-posterior radiograph.

The lower end of the fibula is normally separated from the fibular notch of the tibia by a narrow space, occupied by a strong interosseous ligament: on the radiograph one of the arms of the fibular notch is superimposed on the fibula. Usually no articular surfaces are present between the lower ends of the tibia and fibula, and as the bones are joined by an interosseous ligament, this articulation is a fibrous joint.

The articular areas of the malleoli and talus are shown in profile with a clear joint space, as the leg is rotated medially to separate the bone shadows.

The lateral malleolar articular surface is curved slightly outward and is seen to be much longer than the medial malleolar surface.

The malleolar fossa is visible as a shallow groove near the tip of the lateral malleolus.

Beneath the talus the calcaneus is visible, but this projection is of no practical value in the examination of that bone or of the other tarsal bones which may be demonstrated.

Ankle Joint : Lateral Radiograph (Fig. 77)

The shadows of the lower thirds of the shafts of the tibia and fibula converge at the ankle joint, although the lateral malleolus is still a little posterior to the medial malleolus.

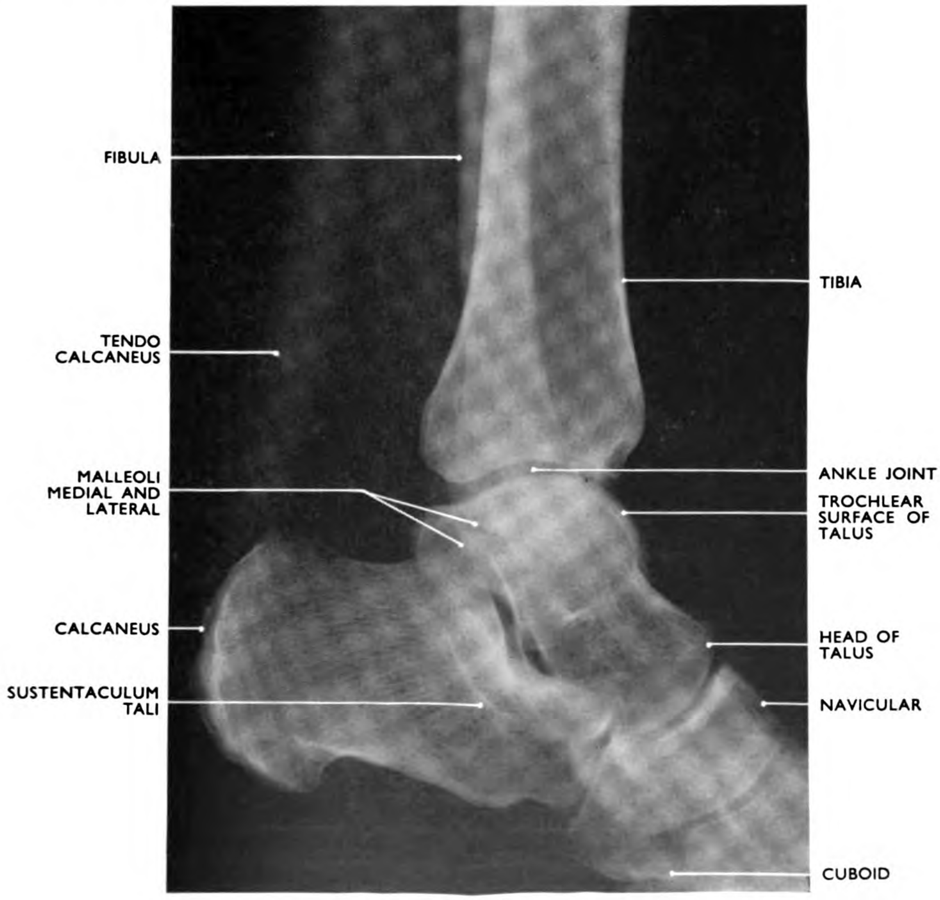


FIG. 77
Left ankle joint : lateral radiograph.

The malleoli overshadow one another and the body of the talus. Although the lateral malleolus is longer than the medial malleolus, the shadows appear

almost the same length, due to the fact that the lateral one is in contact with the film whereas the medial side of the ankle is some distance from it.

The concave inferior surface of the tibia is seen to fit over the convex curve of the trochlea of the talus; the trochlear articular surface is almost twice as extensive in an antero-posterior direction as the tibial articular surface, and allows for a moderate range of dorsiflexion and plantar flexion of the foot on the leg. It will be appreciated from the antero-posterior and the lateral radiographs that the ankle joint is a hinge joint, capable only of dorsiflexion and plantar flexion: the malleoli embrace the talus on both sides and, reinforced by the ligaments of the ankle joint, strongly resist any lateral or medial movement or rotation of the talus.

The calcaneus, navicular and cuboid bones of the tarsus are also demonstrated on this radiograph, and their appearances are similar to those seen in the lateral radiograph of the foot. The curved posterior talo-calcanean joint is partly visible, with the clear shadow of the anterior end of the sinus tarsi immediately in front. The laminations of spongy bone in the calcaneus are well demonstrated and show how the bone is constructed to receive its considerable share of body weight transmitted through the talus at the summit of the arch, the laminations following the lines of force. The tendo calcaneus is inserted into the middle third of the posterior surface of the calcaneus and its shadow is faintly visible, separated from the shadow of another group of muscles of the calf by a dark triangular area containing fatty tissues.

Ligaments of the Ankle Joint

The ankle joint is a strong joint, not only because of its peculiar mortise-like construction, but also because it is invested with strong ligaments, principally on the medial and lateral sides.

The medial or deltoid ligament fans out from the apex of the medial malleolus into a number of bands, attached from before backward to the navicular, sustentaculum tali, and posterior process of talus.

The lateral ligament consists of three separate bands which radiate from the lateral malleolus; an anterior band passes to the anterior part of the talus, a middle band is inserted on the outer surface of the calcaneus and the posterior band is attached to the posterior part of the talus.

Injuries to the ligaments cannot be directly demonstrated by X rays as they are normally not visible. However, indirect evidence of injury can sometimes be assessed by taking an antero-posterior radiograph of the ankle with forced inversion or eversion of the foot. Normally the joint space between the tibia and the talus during such a manoeuvre remains almost uniform in width: widening of the joint space on either side would indicate an injury to the ligaments.

Ossification of the Tibia and the Fibula (Fig. 78)

Each bone develops from one primary centre for the shaft and one secondary centre for each end. The primary centre for the tibia appears about the seventh week of intrauterine life and for the fibula in the eighth week.

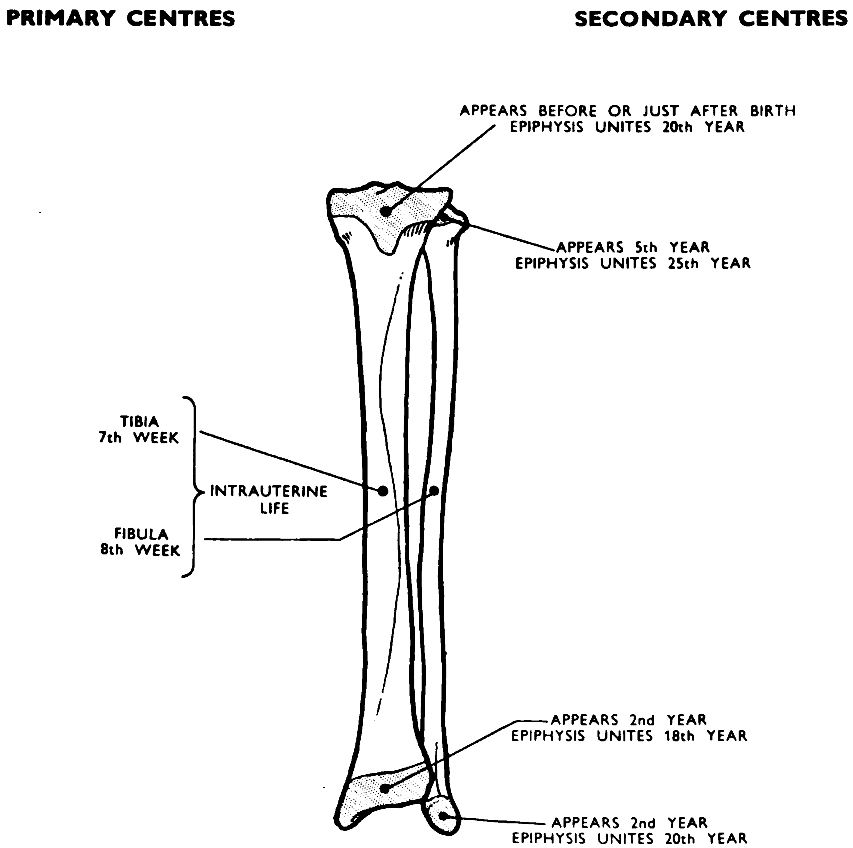


FIG. 78
Ossification of tibia and fibula.

The secondary centres for the ends of the bones appear between birth and the fifth year. The epiphyses at the lower ends unite with the shafts about the eighteenth year, but the upper epiphyses do not fuse until the twentieth year since the knee joint area is the site of maximum growth in length in the lower limb. The tibial tuberosity may develop from a tongue-like downward extension of the upper tibial secondary centre or it may develop from an additional secondary centre appearing about the twelfth year.

The development of the secondary centres is demonstrated in Figures 79, A and B.

A 3 YEARS B

FIG. 79
Ossification of tibia and fibula.

THIGH BONE

Femur (Fig. 80)

The femur, or thigh bone, is the longest bone in the body. It consists of an upper end carrying a conspicuous rounded head, a strong shaft and an expanded lower end. The head articulates with the pelvis at the hip joint and the lower end articulates with the tibia and the patella to form the knee joint.

The Upper End is composed of the head, the neck and two bony prominences, named the greater and lesser trochanters. The head and neck are inclined at an angle to the line of the shaft.

The **head** forms about two-thirds of a sphere and is directed upward and medially to articulate with the acetabulum of the hip bone. Its surface is smooth, except for a small depression below the centre called the fovea, and is covered with articular cartilage. A ligament, the ligament of the head of the femur (ligamentum teres), extends from the fovea to the sides of the acetabular notch.

The **neck** is elongated and slightly flattened to give an anterior and posterior surface and an upper and lower border. It joins the shaft at an angle of approximately 125°, and its length is sufficient to ensure that the lower limb swings free of the pelvis.

The upper border of the neck is short, almost horizontal and slightly concave. The lower border is longer and runs obliquely downward.

On the anterior surface of the junction of the neck and the shaft is a bony ridge, the intertrochanteric line, whilst on the posterior surface is the intertrochanteric crest. The trochanters are placed one at each end of this conspicuous crest. In the middle of the intertrochanteric crest a small bony elevation, the quadrate tubercle, is present.

The strong capsular ligament of the hip joint arising from the acetabulum is attached below to the base of the neck, with a more extensive attachment to the anterior than the posterior surface.

The **greater trochanter** is a prominent bony mass projecting upward and laterally from the junction of the neck and shaft. It is four-sided in shape and has a roughened surface for muscle insertions, which include most of the muscles of the buttock. The upper posterior corner of the greater trochanter extends medially to overhang the trochanteric fossa into which is inserted the obturator externus muscle of the pelvis.

The **lesser trochanter** is a small conical process, projecting medially from the lower end of the intertrochanteric crest, at the junction of the neck and shaft of the femur. The psoas major muscle, which arises from the lumbar vertebral bodies, is inserted into the lesser trochanter.

The Shaft of the femur is long and cylindrical. In the human body the femora are inclined downward and medially so that the knees are almost in contact. The degree of medial inclination is governed by the width of the

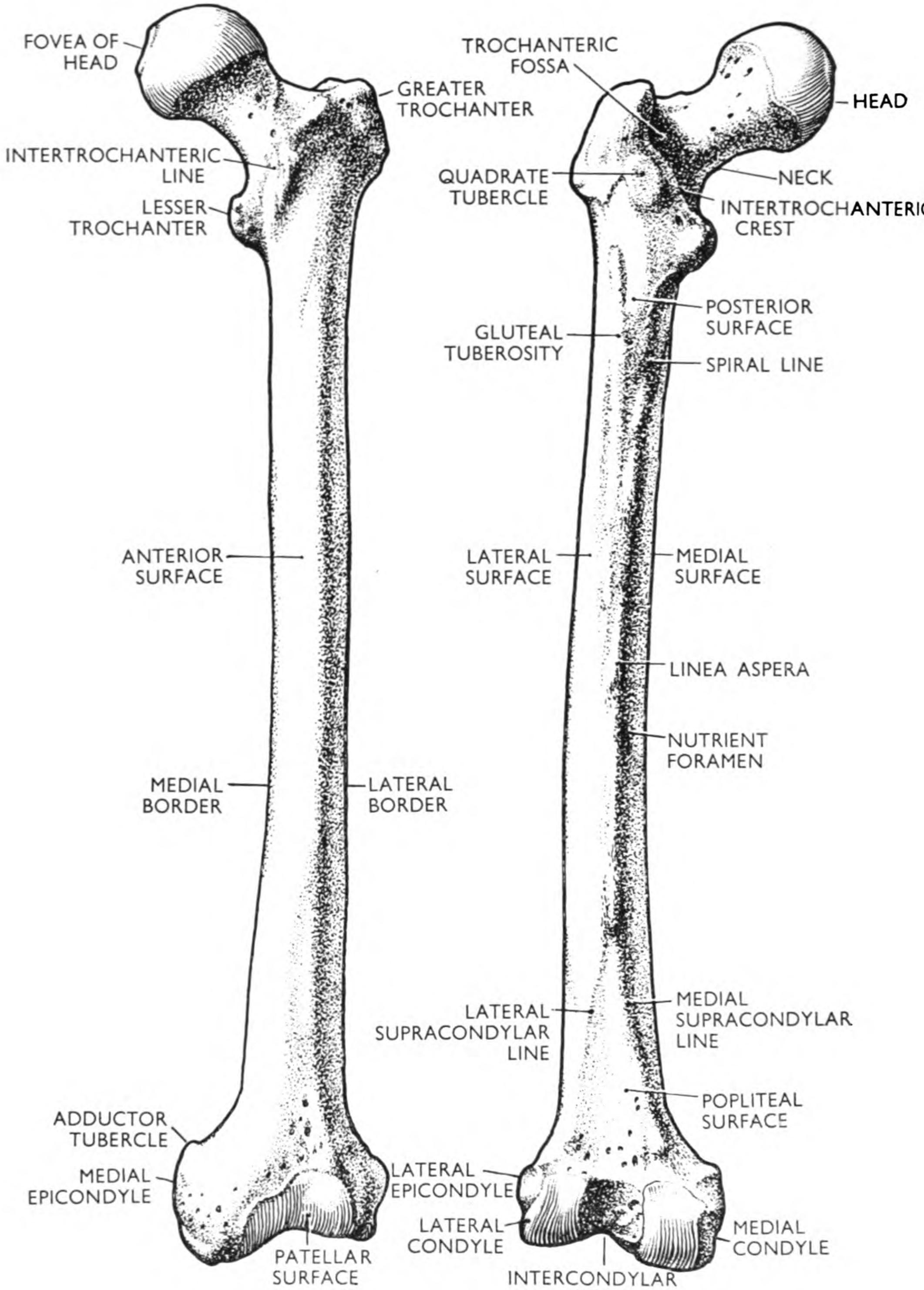


FIG. 80

Left femur: anterior aspect. Left femur: posterior aspect.

pelvis separating the hip joints. The shaft also has a slight forward convexity which is compensated for by a well-marked bony ridge on the posterior aspect, the linea aspera.

The middle part of the shaft has three surfaces—anterior, medial and lateral. The prominent linea aspera forms the posterior border: the medial and lateral borders are ill defined. The linea aspera gives attachment to some of the large muscles of the thigh.

The anterior surface is smooth and convex. A nutrient foramen is present in the middle third of the medial surface.

The upper posterior end of the shaft widens to create a V-shaped posterior surface, bounded by bony ridges which converge inferiorly to become continuous with the linea aspera. The ridge on the lateral side is called the gluteal tuberosity and gives attachment to the gluteus maximus, the largest

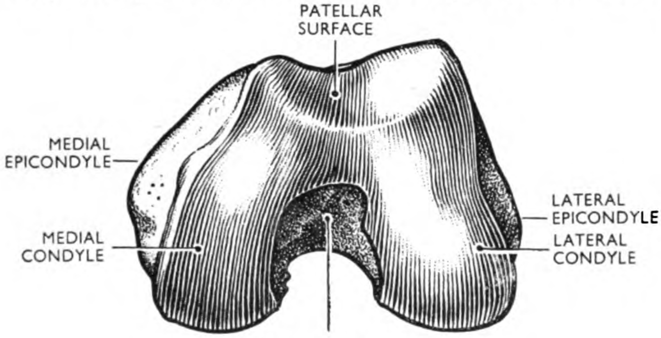


FIG. 81
Left femur: inferior aspect.

muscle of the buttock. The medial ridge is known as the spiral line, and it extends downward from the region of the lesser trochanter.

In the lower third of the posterior surface of the shaft, the linea aspera divides into the medial and lateral supracondylar lines which run obliquely down to the femoral condyles. The triangular area between the lines is called the popliteal surface, over which the popliteal artery passes.

The Lower End of the femur is expanded from side to side and is formed by the medial and lateral condyles. The condyles present a united anterior surface, in line with the anterior surface of the shaft of the femur: posteriorly they project beyond the line of the shaft and are divided by a deep intercondylar notch (Fig. 81). The condyles are markedly convex from front to back and each condyle is slightly convex from side to side. The articular surface is continuous across the anterior surface of the condyles, with a shallow median groove with which the patella articulates; it extends inferiorly and posteriorly on each condyle and is separated by the intercondylar notch.

The femoral condyles do not exactly conform in shape to the shallow

concave facets of the tibial condyles, but this is partly compensated for by the interposed semilunar cartilages.

The **medial condyle** has a roughened prominence on its medial aspect, the medial epicondyle. Above the epicondyle is the adductor tubercle, into which the adductor magnus muscle of the inner side of the thigh is inserted. The rough lateral wall of the condyle forms one wall of the intercondylar notch, and gives insertion to the posterior cruciate ligament.

The **lateral condyle** is slightly larger and stronger than the medial condyle, since it takes more of the body weight. A small bony projection, the lateral epicondyle, is present on its lateral surface, and below is a groove which gives origin to the popliteus muscle.

The cruciate ligaments are two strong rounded ligaments which extend from the non-articular intercondylar notch of the femur to the non-articular intercondylar area of the tibia. They cross each other within the joint capsule like an X and form, with the tibial and fibular collateral ligaments, the main bonds between the femur and tibia.

Patella (Figs. 82 and 83)

The patella is the largest sesamoid bone in the body. It lies in the tendon of the quadriceps femoris muscle on the anterior aspect of the knee joint and

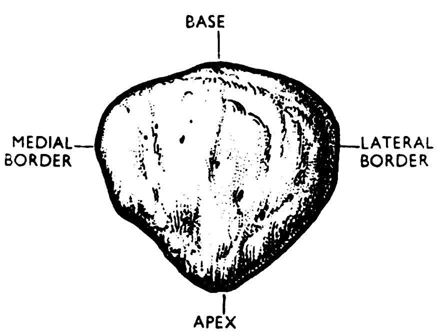


FIG. 82
Left patella: anterior aspect.

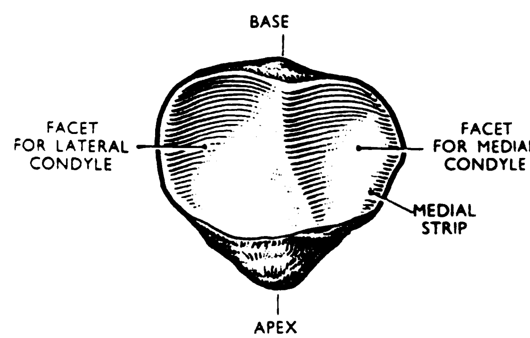


FIG. 83
Left patella: posterior aspect.

articulates with the femoral condyles. It is roughly triangular in shape, with a thick superior border and thinner medial and lateral borders, which converge to an apex. The apex is situated about one inch above the joint space of the knee when the leg is extended.

The patella has an anterior and a posterior surface.

The **anterior surface** (Fig. 82) has vertical grooves and ridges for attachment to the muscle tendon in which it is situated.

The **posterior surface** (Fig. 83) is mainly covered with articular cartilage, and is divided by a median ridge into two unequal facets. This contour corresponds to the slight concavity present on the anterior femoral articular surface with which the patella articulates. The lateral articular facet of the

patella is slightly larger than the medial facet. The ligamentum patellae is inserted into a small rough area at the apex of the posterior surface.

Over the range of movement of the knee joint only a limited area of the patella is in contact with the femoral condyles at any one time. On extension

FIG. 84
Right knee: lateral series from extension to flexion.

the lower part of the patella is in contact with the upper part of the femoral articular surface. In full flexion about half of the patellar surface articulates with the inferior surfaces of the femoral condyles. These movements can be studied in Figure 84, A to D.

Fabella

The fabella is an inconstant sesamoid bone in the lateral head of the gastrocnemius muscle. This important muscle of the calf arises from the

posterior surface of the medial and lateral condyles of the femur and its tendon, with that of the soleus muscle, forms the tendo calcaneus. The fabella is found where the lateral head of the muscle passes over the lateral condyle of the femur.

Knee Joint

The contours of the articular surfaces of the knee joint would not suggest it to be a strong joint, yet the surrounding ligaments and muscles combine to make it one of the strongest. The semilunar cartilages are, however, the weakest links in the stability of the knee joint, and are often dislocated or torn.

Movement at the joint is not simply that of a hinge joint, but includes a small degree of medial and lateral rotation of the tibia on the femur, in flexion and extension respectively. In addition, the axis of rotation of the tibia on the femur moves forward on extension and backward on flexion. During these combined movements the semilunar cartilages play an important part by slightly changing their position and shape to adapt the tibial and femoral articular surfaces to each other.

RADIOGRAPHIC APPEARANCES OF THE FEMUR

Femur : Antero-posterior Radiograph (Fig. 85)

This full-length radiograph demonstrates the main bony features of the femur.

At the top of the radiograph the rounded head of the femur is seen within the shadow of the acetabulum of the hip joint. Below the head, the neck runs laterally and slightly downward to meet the shaft at an angle of approximately 125°. At the junction of the neck and shaft the trochanters are clearly visible: between these two processes the shadows of the intertrochanteric line and crest are superimposed.

The long cylindrical shaft presents no particular radiographic features, although the thickness of the compact bone indicates its strength.

At the lower end the outlines of the posterior projection of the condyles can be seen through the main mass of bone, and the faint shadow of the patella is visible above the lower margin of the intercondylar notch.

Femur : Lateral Radiograph (Fig. 86)

It is not possible to take a full-length lateral radiograph of the femur, as there is a marked difference in radiographic density between the upper thigh and buttock and the lower thigh. Only the lower two-thirds of the femur are demonstrated in Figure 86.

The slight forward convexity of the shaft is evident. The linea aspera on the posterior border gives an added thickness to the compact bone. The

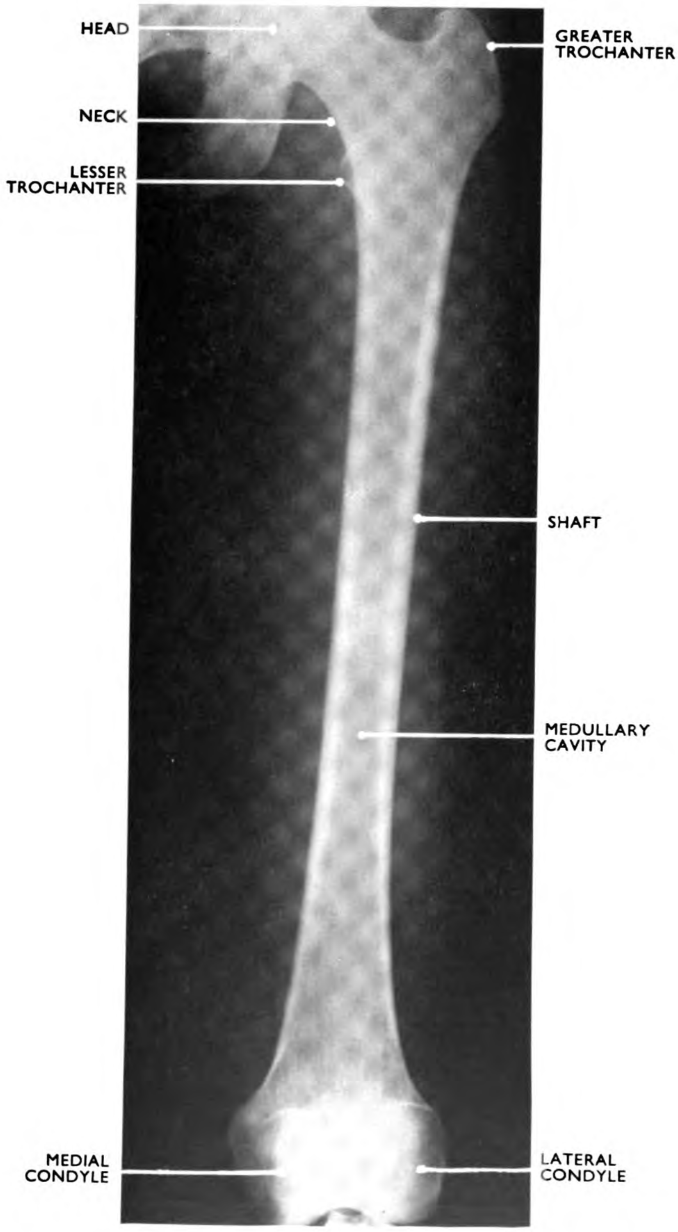


FIG. 85
Left femur: antero-posterior radiograph.

posterior muscles of the thigh are faintly outlined. The medial and lateral condyles of the femur are separately visible and their posterior projection can

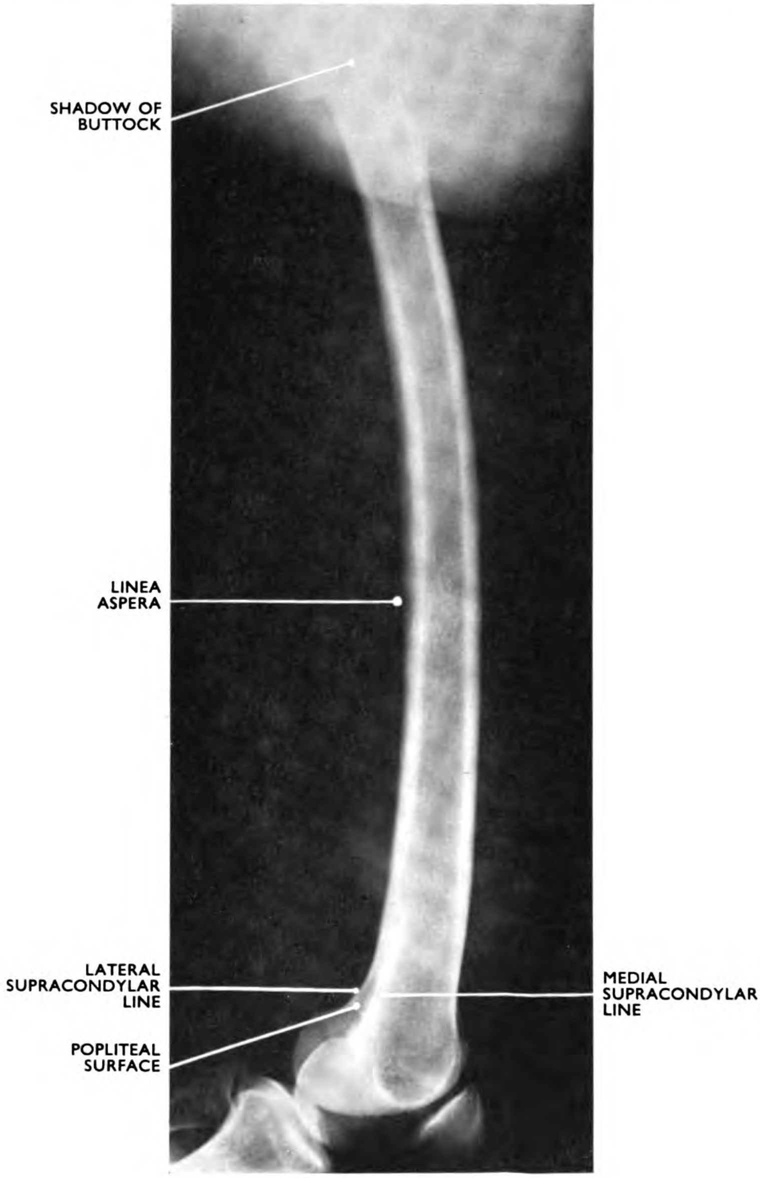


FIG. 86
Right femur: lateral radiograph.

be appreciated. The supracondylar lines which extend downward to the posterior surfaces of the condyles are visible: these lines enclose the popliteal surface of the femur. The patella and upper end of the tibia are also shown.

Knee Joint : Antero-posterior Radiograph (Fig. 87)

This radiograph includes the lower third of the femur, the upper third of the tibia and fibula, and the patella.

A prominent bony feature of the medial surface of the medial femoral condyle is the adductor tubercle, situated at the upper extremity: below is the slight elevation of the medial epicondyle.

The lateral epicondyle is visible on the lateral margin of the lateral condyle.

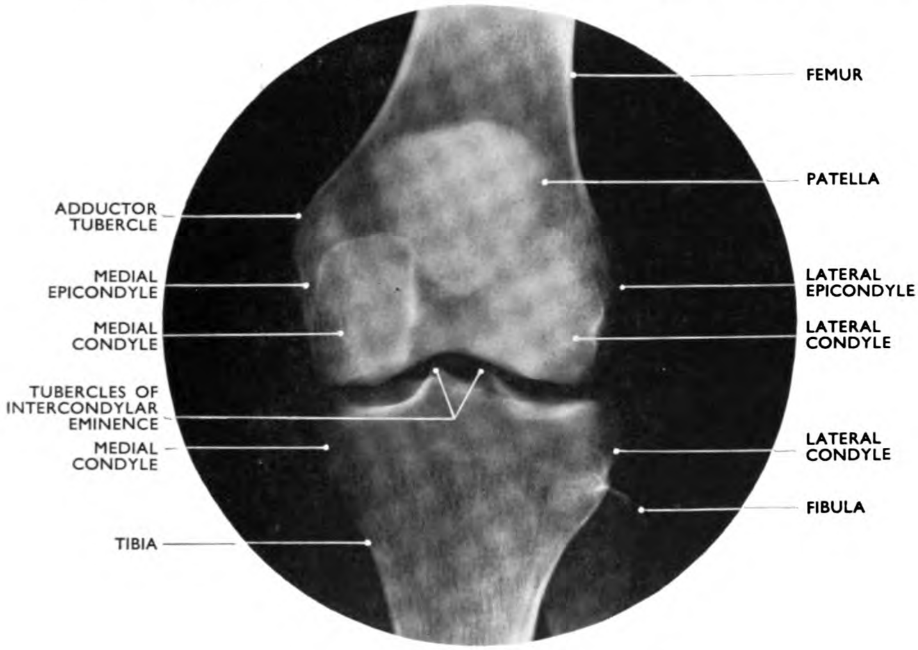


FIG. 87
Left knee: antero-posterior radiograph.

The posterior projection of the femoral condyles is visible as denser, roughly rectangular areas of bone, one on either side of the midline: between them lies the intercondylar notch, of which the lower margin is seen in profile as a slight concavity in the middle of the inferior surface. Immediately opposing the intercondylar notch are the tubercles of the intercondylar eminence of the tibia. The opposing convexity and concavity of the femoral and tibial condyles respectively is well shown: the interposed semilunar cartilages do not normally cast a shadow, but their presence accounts for the unusually wide joint space.

The roughly triangular shape of the patella can be seen: its outline is ill-defined in this radiographic projection owing to its distance from the film. As the leg is extended, the patella is high up on the condyles, with the apex approximately one inch above the joint space of the knee.

The head of the fibula is partly overshadowed by the lateral condyle of the tibia and the styloid process is completely obscured.

If a line is drawn through the centre of the tibia at right angles to the joint space, it will be seen that the long axis of the femur inclines upward and laterally.

Knee Joint : Postero-anterior Radiograph (Fig. 88)

This view is of particular value in the examination of the patella, since it is very much nearer the film in the postero-anterior position : magnification of the image is reduced to a minimum, and good definition of bone structure is obtained.

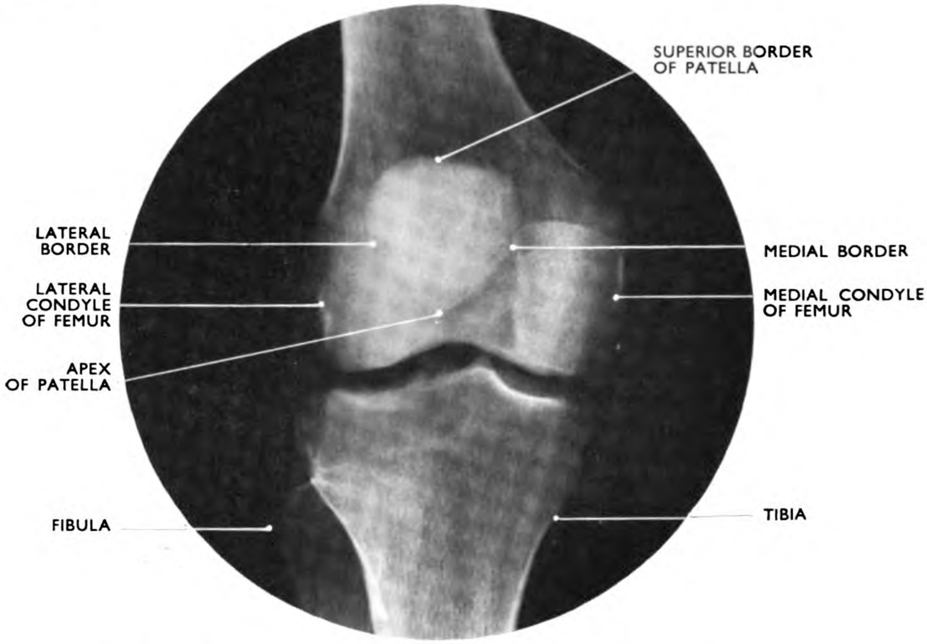


FIG. 88
Left knee : postero-anterior radiograph for patella (from tube aspect).

Compare Figure 87 with Figure 88, radiographs of the same knee from the two different aspects.

Knee Joint : Lateral Radiograph (Fig. 89)

Unless injury to the patella is suspected, the lateral radiograph of the knee is taken with partial flexion at the joint.

The outlines of the femoral condyles are superimposed, and their posterior projection is well demonstrated. Inside the outlines of the condyles can be seen a line of denser bone, continuous with the compact bone on the anterior and posterior aspects of the shaft. Posteriorly and inferiorly this line is cast by the compact bone on the floor of the intercondylar notch : anteriorly it is cast by the compact bone at the base of the slight vertical concavity between the condyles. It therefore demonstrates the shape of the junction of the condyles in the midline.

The slight concavity of the tibial condyles does not match the convexity

of the femoral condyles, but the semilunar cartilages situated on the tibial condyles help to deepen this concavity. The slightly raised intercondylar eminence of the tibia is visible, and the tubercles can be traced, although partly overshadowed by the femoral condyles.

The overhang of the tibial condyles partly obscures the head of the fibula,

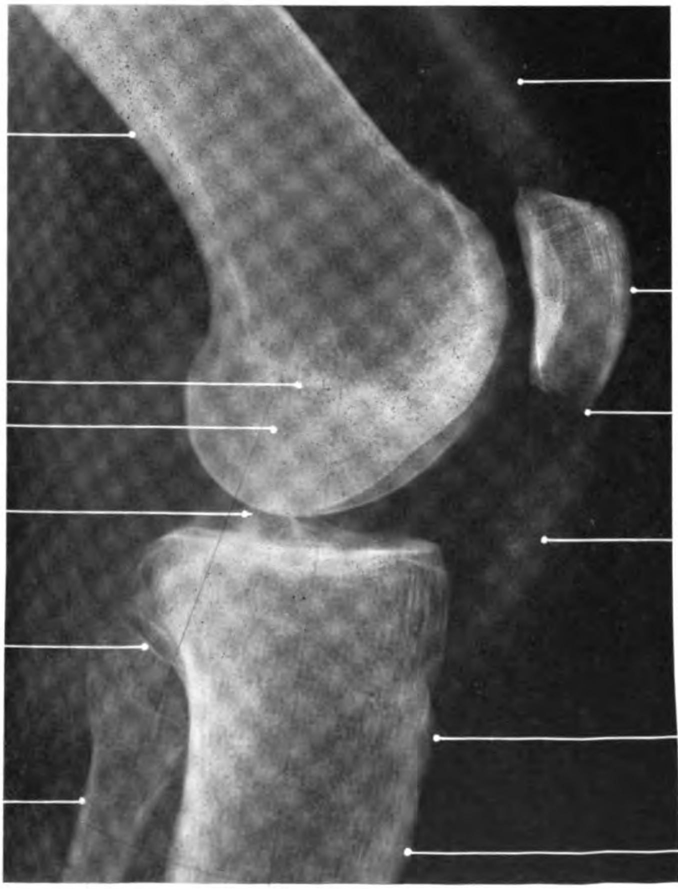


FIG. 89
Left knee: lateral radiograph.

although the upper part of the superior tibiofibular joint and the styloid process are clearly seen.

The lateral view of the patella shows that its femoral articular surface does not exactly correspond to that of the opposing femoral condyles: only a small area is in contact at any time.

The outline of the quadriceps muscle which is inserted in the thick upper border of the patella is faintly visible. The ligamentum patellae arising from the apex of the patella can be traced to its insertion on the tibial tuberosity.

The muscles on the posterior aspect of the knee joint are faintly outlined.

Patella : Infero-superior Radiograph (Fig. 90)

This radiograph, sometimes called an axial view of the patella, clearly shows the division of the femoral articular surface by a bony ridge into a larger lateral and a smaller medial facet.

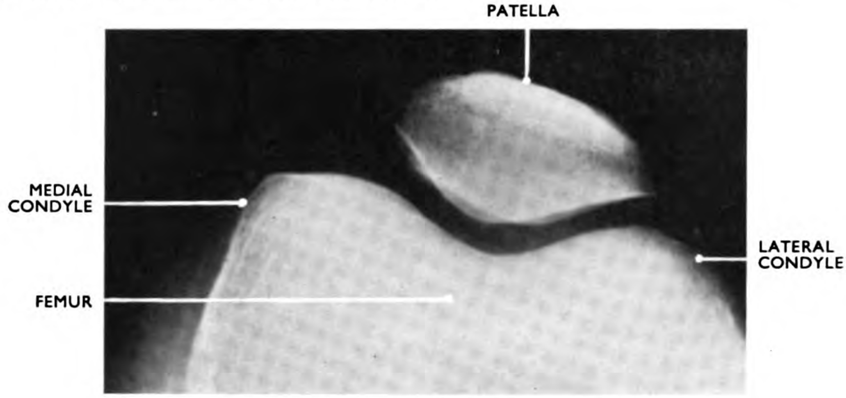


FIG. 90
Patella : infero-superior radiograph.

Fabella : (Figs. 91 and 92)

This pair of radiographs of the same knee shows the position of the fabella. This small inconstant sesamoid bone lies in the outer head of the gastrocnemius muscle, where it passes over the posterior surface of the lateral femoral condyle.

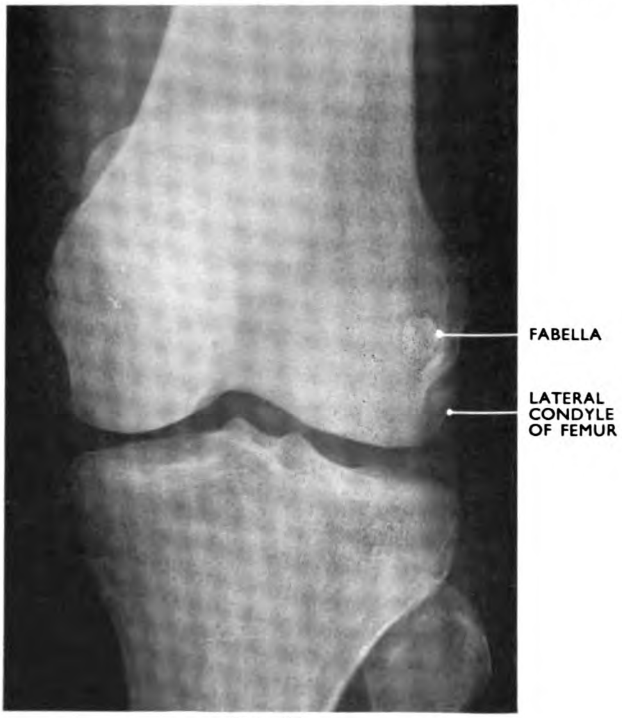


FIG. 91
Left knee : antero-posterior radiograph showing fabella.

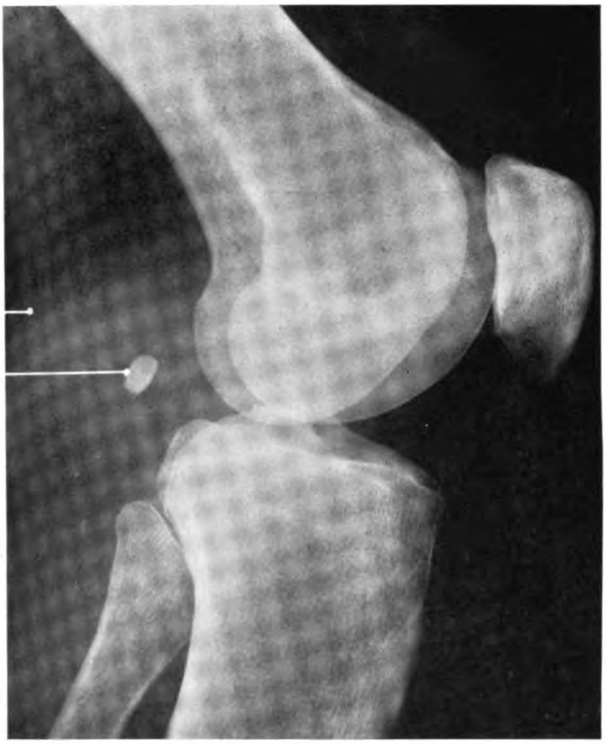


FIG. 92
Left knee: lateral radiograph showing fabella.

Knee Joint : Pneumo-arthrography (Figs. 93 and 94)

It is sometimes necessary to examine the internal structure of a joint, and this can be accomplished by the injection of a contrast medium into the synovial cavity. The contrast medium often employed is air or oxygen, and the examination is known as pneumo-arthrography.

In the case of the knee joint, pneumo-arthrography is usually carried out to ascertain possible damage to the semilunar cartilages.

The extent of the synovial cavity is evident in Figure 93, a lateral radiograph taken after air has been introduced. The air is more transradiant than bone or soft tissues and therefore the synovial cavity is seen as a darker area. The extensive upward extension of the synovial cavity above the patella (the supra-patellar bursa) is well demonstrated. Inferiorly, the cavity is separated from the ligamentum patellae by an extrasynovial pad of fat (infrapatellar pad). The cruciate ligaments are faintly outlined, but the semilunar cartilages are not clearly seen in this view. Posteriorly, the cavity extends over the posterior articular surface of the femoral condyles. There is only a small extension below the level of the tibial condyles, which otherwise mark its inferior margin: this extension or recess is on the posterior surface of the lateral condyle.

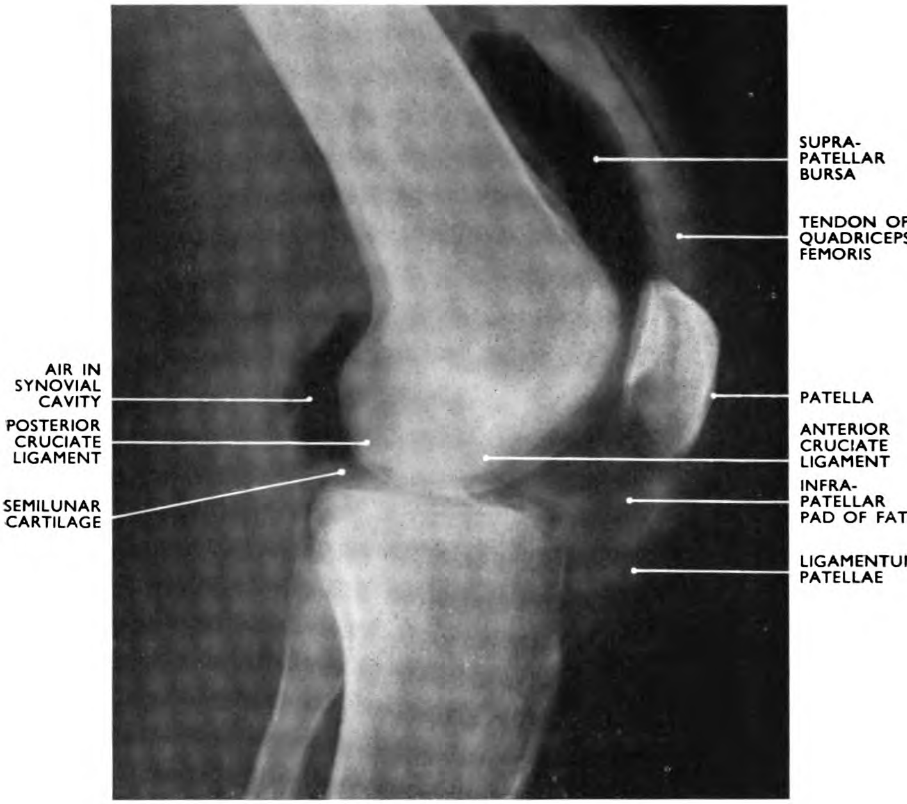


FIG. 93
Knee joint: pneumo-arthrography.

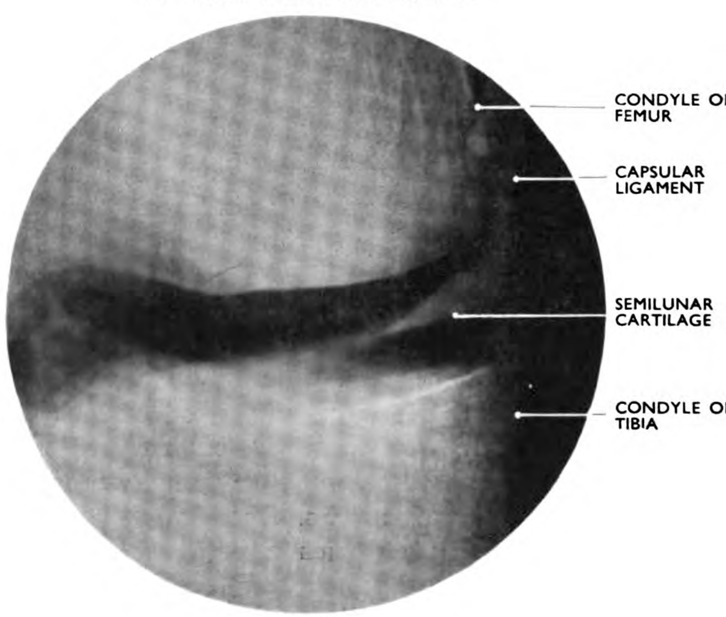


FIG. 94
Knee joint: pneumo-arthrography.

In Figure 94, an oblique radiograph of the knee, the air is seen as a dark shadow above and below the medial semilunar cartilage, which is visible as a wedge-shaped shadow. The capsular ligament is also visible.

Ossification of the Femur and Patella (Fig. 95)

The **femur** ossifies from one primary centre for the shaft, three secondary centres for the upper end and one secondary centre for the lower end.

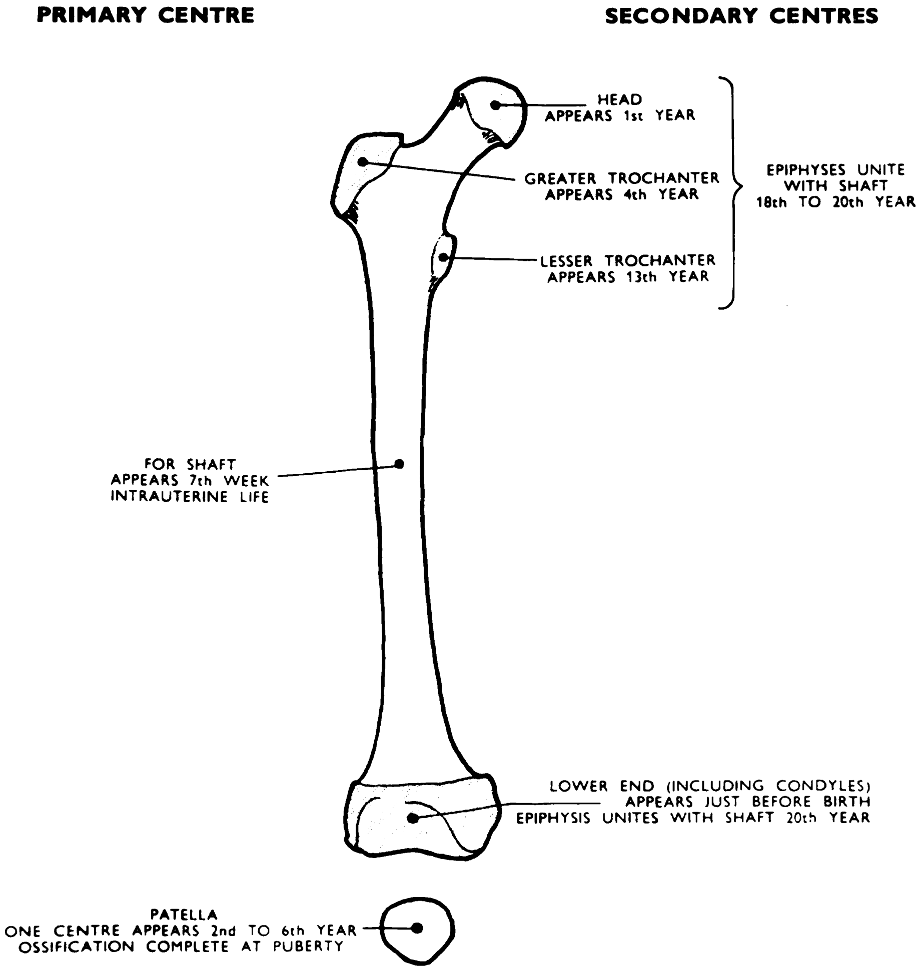


FIG. 95
Ossification of femur and patella.

Ossification of the shaft begins early in foetal life. The secondary centre for the head appears during the first year, for the greater trochanter about the fourth year and for the lesser trochanter about the thirteenth year. These epiphyses fuse with the shaft between the eighteenth and twentieth year. The

A

4 YEARS

B

7 YEARS

FIG. 96

Ossification at the knee.

secondary centre for the lower end appears during the ninth month of intra-uterine life, *i.e.*, just before birth. Its presence on a radiograph of the foetus ***in utero*** indicates that the foetus is at or near full term.

The **patella** ossifies from one primary centre only, which appears between the second and sixth year. Ossification is complete at puberty.

The series of radiographs (Figs. 79, A and B, and 96, A and B) demonstrate the development of the epiphyses in the knee joint region.

CHAPTER IV

PELVIS

THE pelvis is a complete bony ring. It is composed of two hip bones, the sacrum and the coccyx. The two hip bones form the anterior and lateral portions of the ring and meet in the midline in front. Posteriorly the ring is completed by the sacrum, an expanded lower section of the vertebral column. The coccyx is the small inferior extremity of the vertebral column, and articulates with the sacrum. The girdle of the lower limb is formed by a single bone—the hip bone.

Hip Bone : (Os Innominatum) (Figs. 97 and 98)

The hip bone is large and irregular in shape, with a narrow middle section in which is situated a cup-shaped articular area—the acetabulum. The head of the femur articulates with the acetabulum to form the hip joint. The hip bones articulate posteriorly with the sacrum at the sacro-iliac joints and with each other in front at the symphysis pubis.

Each hip bone consists of three parts—the ilium, the ischium and the pubis. In childhood these three parts are separated from each other by a Y-shaped cartilaginous strip which is centred in the acetabulum; bony fusion takes place about puberty.

The ilium is situated mainly above the acetabulum. It is large and flattened with a long, curved, superior margin—the iliac crest.

The ischium and pubis lie mainly below the acetabulum and have bony arms or rami which enclose the obturator foramen.

The hip bone has an external and an internal surface. The external surface bears the acetabulum in which the head of the femur articulates. The internal surface forms the anterior and lateral walls of the pelvic cavity, whilst the sacrum provides the posterior wall.

The **ilium** consists of two parts, an expanded and slightly curved plate of bone above and a smaller section below. The lower part forms nearly two-fifths of the acetabulum, and a small part of the wall of the true pelvis.

The upper expanded part is bounded above by the **iliac crest,** to which are attached numerous muscles of the abdominal wall and back. The sinuous curve of the crest ends in front at the anterior superior iliac spine, and posteriorly at the posterior superior iliac spine.

The **anterior superior iliac spine** is an important surface marking and can be felt at the lateral end of the fold of the groin. The posterior superior iliac spine is located at the bottom of a small depression in the skin of the buttock a short distance from the midline.

Behind the anterior superior spine is a bony prominence, the tubercle of the crest, which lies at the level of the fifth lumbar vertebra. Posterior to the tubercle the highest part of the crest may reach to the level of the fourth lumbar vertebra.

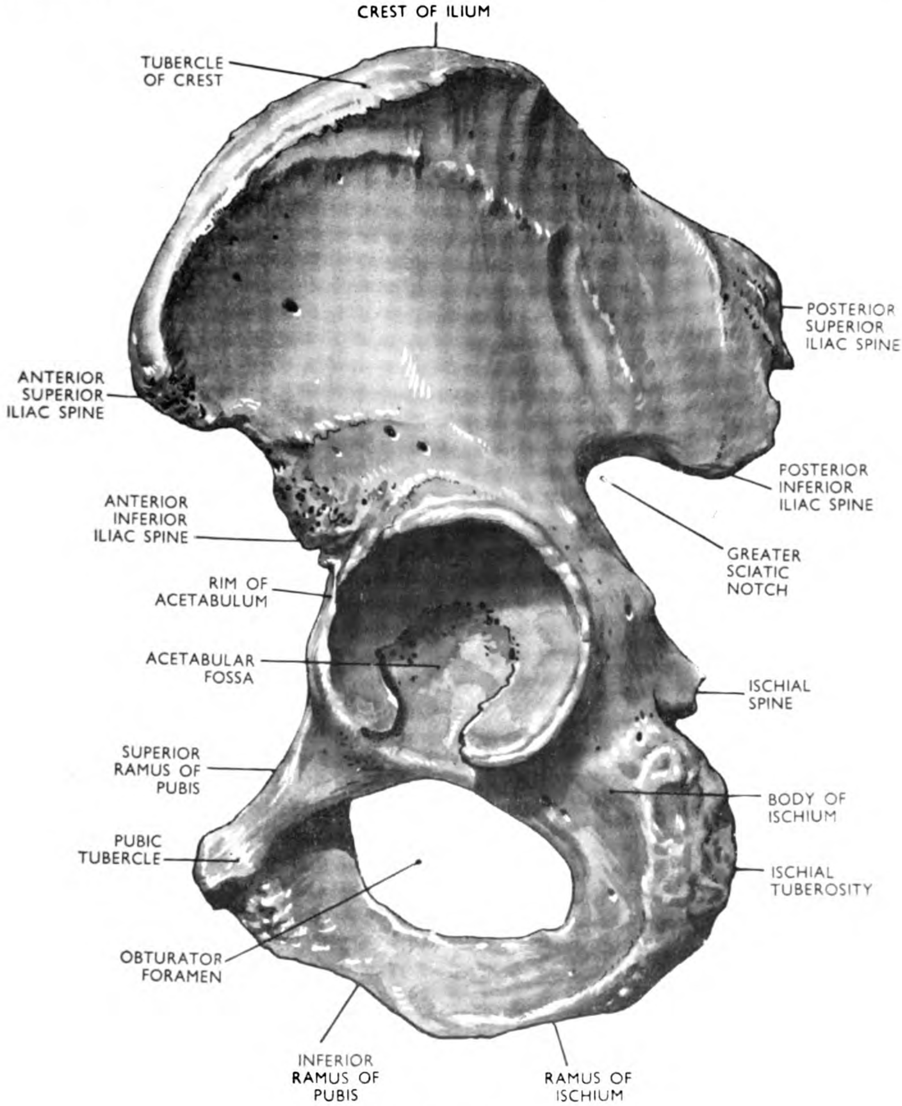


FIG. 97
Left hip bone: external surface.

The **anterior border** of the ilium extends downward from the anterior superior iliac spine to the acetabulum; immediately above the acetabulum is a slight bony prominence, the anterior inferior iliac spine.

The **posterior border** of the ilium commences at the posterior superior iliac

spine and extends downward and forward to become continuous with the posterior border of the ischium. The posterior inferior spine lies an inch below the posterior superior spine, and from this point the posterior border turns sharply forward and then downward to form the upper part of the greater sciatic notch, through which the sciatic nerve passes out of the pelvis into the thigh and leg.

The **internal or medial surface** of the ilium is divided into two areas, the iliac fossa and the sacropelvic surface, by the medial border which runs obliquely forward and downward across the bone from the posterior part of the iliac crest to the iliopectineal eminence. The medial border (arcuate line) forms the iliac part of the iliopectineal line and is part of the brim of the true pelvis.

The **iliac fossa** lies between the medial and anterior borders, and is a large, shallow, concave surface.

The **sacropelvic surface** lies between the medial and posterior borders. The upper part, roughened and pitted for ligamentous attachment, is called the iliac tuberosity. The middle part bears the large, curved, auricular surface for articulation with the sacrum. The lower part is smooth and is bounded posteriorly by the greater sciatic notch; it forms a small part of the lateral wall of the true pelvis.

The **external surface** of the ilium is divided into a large gluteal surface above and a small acetabular portion below. The gluteal surface is crossed by three roughened ridges, the gluteal lines, which divide it into areas of attachment for the gluteal muscles of the buttock.

The **pubis** is the smallest of the three parts of the hip bone and is situated anteriorly. It joins the pubis of the opposite side in the midline at the symphysis pubis and forms the anterior wall of the pelvis. It consists of a body and a superior and an inferior ramus. The superior ramus joins the ilium at the iliopectineal eminence and forms part of the acetabulum. The inferior ramus joins the ramus of the ischium to enclose the obturator foramen. The body is at the junction of the two rami.

The **body** of the pubis is flat, and in the standing position its anterior surface faces downward and forward. The posterior wall faces backward and upward and forms part of the anterior wall of the true pelvis, where it is closely related to the urinary bladder.

The elongated medial surfaces of the body of the pubic bones face one another and are joined by a cartilaginous disc (the symphysis pubis).

The upper border of the body is called the pubic crest: this ridge can be felt beneath the skin and is a very important surface-marking in radiography. On the lateral side of the pubic crest is a small prominence, the pubic tubercle, which gives attachment to the inguinal ligament: the lateral end of this ligament is inserted into the anterior superior iliac spine.

The **superior ramus** extends laterally and slightly upward to join the ilium and the ischium at the acetabulum. The iliopectineal eminence is situated at

its junction with the ilium. Behind its upper border is a ridge, the pectineal line which forms the lower part of the iliopectineal line.

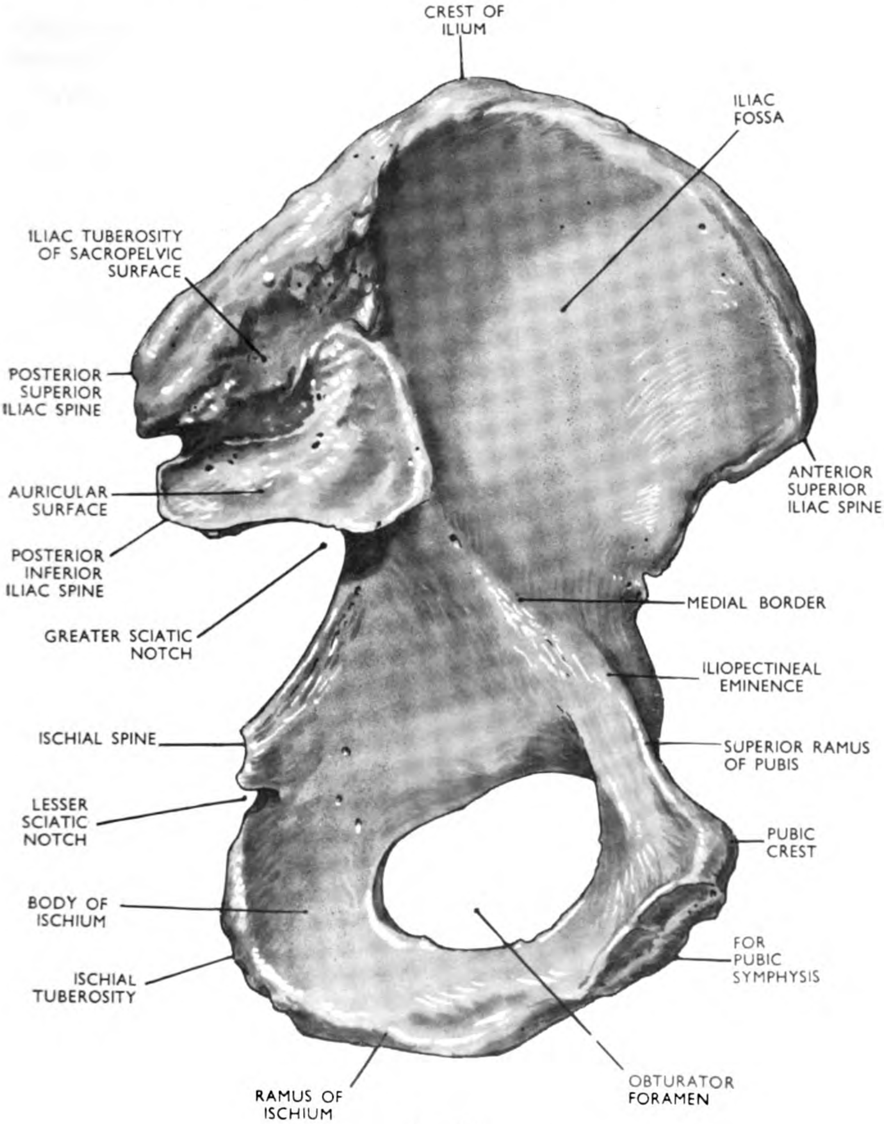


FIG. 98
Left hip bone: internal surface.

The **inferior ramus** passes downward, backward and laterally to join the ramus of the ischium.

The **ischium** constitutes the inferior and posterior part of the hip bone and consists of a body and a ramus.

The **body** of the ischium can be divided into an upper and a lower area: the upper area forms about two-fifths of the acetabulum and the lower part shows a marked prominence--the ischial tuberosity—which gives attachment to the sacrotuberous ligament and to several muscles of the thigh.

The upper part of the posterior border of the body completes the greater sciatic notch; this ends in a well-marked bony protuberance, the ischial spine, below which is the lesser sciatic notch.

Two ligaments, the sacrotuberous and the sacrospinous, convert the greater and lesser sciatic notches into foramina in the living subject (Fig. 106).

The **ramus** of the ischium is thin and flat: it extends slightly upward to join the inferior ramus of the pubis.

A large opening, the **obturator foramen**, is enclosed by the body of the ischium, the ischial ramus and the superior and inferior rami of the pubis. A fibrous membrane closes the foramen, except at its upper edge where an opening transmits vessels and nerves from the pelvis to the thigh and buttock.

The **acetabulum** is a deep cup-shaped depression on the external surface of the hip bone. In the standing figure it faces laterally, slightly forward and downward. It is surrounded by a prominent rim which is deficient below: this gap is known as the acetabular notch. The cup is further deepened in the living subject by a complete cartilaginous ring, the acetabular labrum, which is attached to the bony rim: the part of the labrum which bridges the acetabular notch is known as the transverse ligament of the acetabulum. The articular surface is absent centrally and inferiorly in the region of the acetabular notch. The ligament of the head of the femur which is inserted into the fovea of the femoral head arises from either side of the acetabular notch.

All three parts of the hip bone contribute to the formation of the acetabulum. The Y-shaped cartilage which separates the ilium, ischium and pubis is centred in the base of the acetabulum, but after puberty complete bony fusion takes place between the three parts.

The **hip joints** transmit the weight of the trunk and upper limbs to the lower limbs. For this reason they are strong and stable joints. At the same time, considerable freedom of movement is required to ensure mobility of the lower limbs. The ball-and-socket joint of the hip fulfils these two purposes.

Although the acetabulum is deep the movements of flexion, extension, adduction and abduction can be carried out, but they are not so extensive as the similar movements at the shoulder joint where the glenoid cavity is shallow and the head of the humerus relatively large: this latter type of joint is, however, relatively unstable and dislocation at the shoulder joint is not an uncommon occurrence, whereas dislocation of the hip joint is rare.

Ossification of the Hip Bone (Fig. 99)

The three components of the hip bone—the ilium, ischium and pubis—ossify from separate primary centres in early intrauterine life. They are at first

separated in the acetabulum by the Y-shaped cartilage, but bony fusion takes place about puberty. The rami of the pubis and ischium fuse at an earlier age, about the eighth year.

Five secondary centres appear about puberty and the epiphyses fuse with the hip bone between the twentieth and twenty-fifth year.

The series of radiographs (Fig. 100A to 100C) show the bony development of the hip bone.

PRIMARY CENTRES **SECONDARY CENTRES**

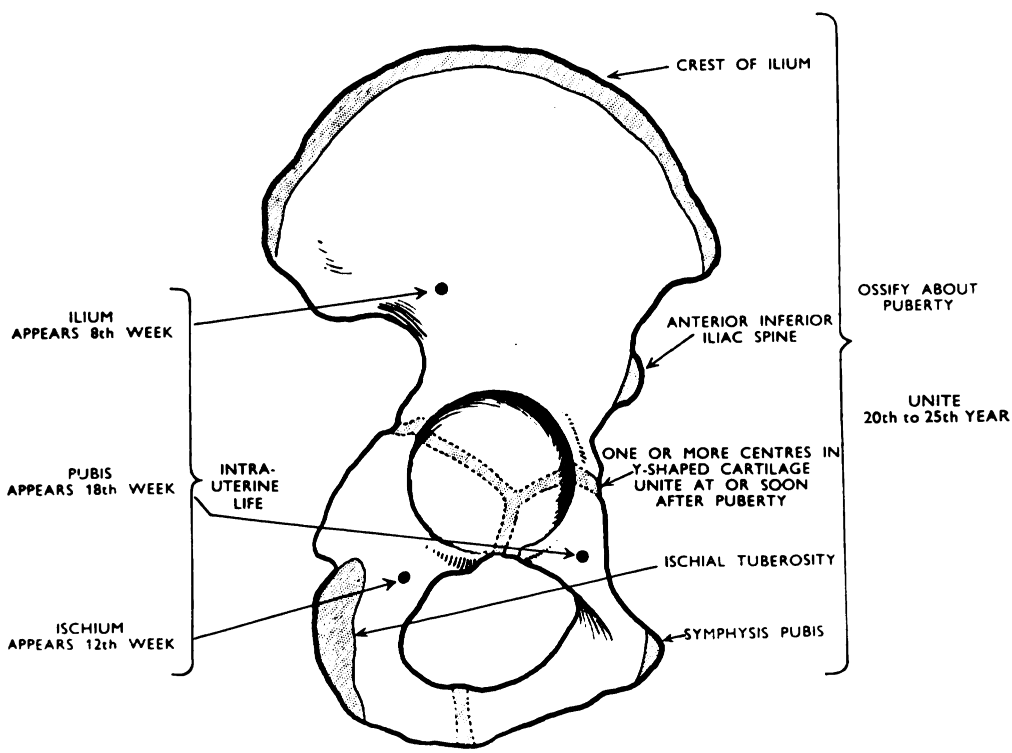


FIG. 99
Ossification of the hip bone.

A child in the first year of life (Fig. 100A) shows complete bony separation of the three parts of the hip bone. The acetabulum and femoral head are still cartilaginous.

Figure 100B is a radiograph of a child just before puberty. The Y-shaped cartilage is still present, but the head of the femur and acetabulum are now well formed. The secondary centres of ossification have not yet appeared.

The radiograph of a young adult (Fig. 100C) shows the secondary centre for the crest of the ilium is still present, as complete ossification of the hip bone does not take place until the twentieth to twenty-fifth year.

1 YEAR

FIG. 100A
Ossification of hip bone.

10 YEARS

FIG. 100B
Ossification of hip bone.

18 YEARS

FIG. 100C

Ossification of hip bone.

Sacrum and Coccyx

No consideration of the pelvis as a whole can be complete without a brief description of the sacrum and coccyx, although they will be described in greater detail later (p. 148).

The **sacrum** is situated at the lower end of the vertebral column and is formed by the bony fusion of five sacral vertebrae. It is large and roughly triangular with the apex pointing downward.

The anterior or pelvic surface is concave with a prominent upper margin, the sacral promontory.

The lateral surface is broad above and narrow below. On the anterior

upper part of the lateral surface is an ear-shaped articular facet, the auricular surface, for articulation with the corresponding auricular surface of the ilium at the sacro-iliac joint. The remainder of the lateral surface is rough for ligamentous and muscle attachment.

The sacrum forms an angle with the lumbar vertebrae above, the lumbo-sacral angle, so that in the living subject the pelvic surface faces forward and downward.

The **coccyx** is a small triangular bone articulating with the lower end of the sacrum. It is variable in size and usually consists of four fused vertebrae.

RADIOGRAPHIC APPEARANCES OF THE PELVIC GIRDLE

Hip Bone and Hip Joint : Antero-posterior Radiograph (Fig. 101)

This radiograph of the left half of the pelvis includes the hip bone and the adjoining sacrum as well as the upper half of the femur and the hip joint.

The hip bone forms the lateral and anterior walls of the pelvis and part of it is therefore oblique to the X rays, particularly that area immediately adjoining the hip joint.

As the acetabulum faces forward, laterally and downward it is seen obliquely. It almost envelops the head of the femur, but the acetabular labrum which further deepens the cup does not cast a shadow. The medial edge of the acetabular notch is faintly visible on the lower margin of the acetabulum, partly obscured by superimposed bone. The fovea at the centre of the head of the femur can be identified as a slight irregularity of the circumference, but the ligament of the head is not visible.

The ilium, which is the largest of the three parts which constitute the hip bone, is situated above the midpoint of the acetabulum in this radiograph. The prominent iliac crest is clearly visible, as are the anterior, superior and inferior iliac spines. Only the anterior margin of the sacro-iliac joint is visible, since the general plane of the joint is oblique to the X rays. At the lower end of the sacro-iliac joint there is a well-defined bony margin which sweeps round to the symphysis pubis. This line, the pelvic brim, separates the false pelvis above from the true pelvis below. If this line is continued posterior to the sacro-iliac joint it reaches the midline on the anterior lip of the first sacral segment (promontory of the sacrum).

The body and superior and inferior rami of the pubis are clearly visible. The narrow gap at the symphysis pubis is due to the cartilaginous disc intervening between the medial surfaces of the bodies of the pubic bones.

The body of the ischium lies in and below the acetabulum. The ischial tuberosity is a clearly defined projection which marks the lower end of the body, whence the ramus of the ischium turns upward, forward and slightly medially to join the inferior ramus of the pubis. The obturator foramen enclosed by

the ischium and pubis is seen obliquely and is therefore larger than appears in this radiograph.

In an antero-posterior radiograph of a patient in the supine posture and correctly positioned, with the foot directed forward, the image of the greater

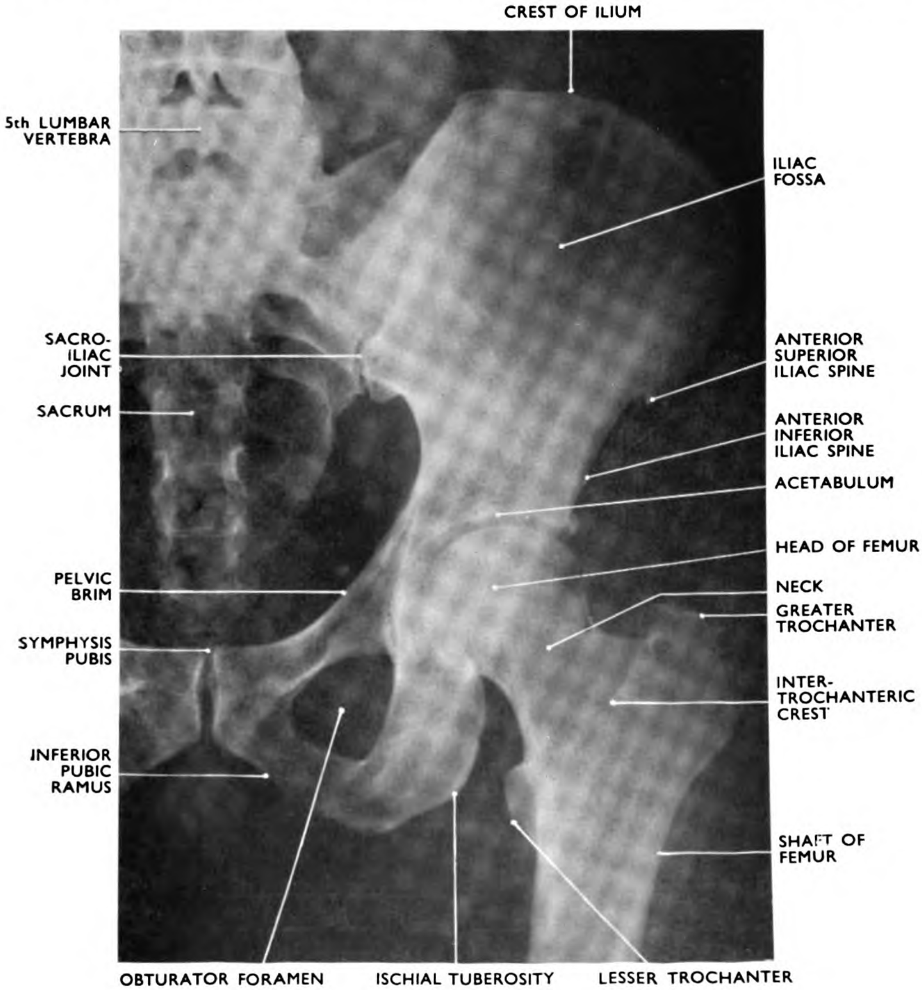


FIG. 101
Left hip bone and hip joint: antero-posterior radiograph.

trochanter is on the lateral side of the neck and the lesser trochanter projects only slightly from behind the shaft, as in Figure 101. Should the leg, by mistake, be left with foot unsupported, it will assume a natural position in lateral rotation. The greater trochanter will then be found behind the shadow of the foreshortened neck and the lesser trochanter will have turned clear of the shaft, producing an image of increased size. The femur in these circumstances is not in an antero-posterior position, but is in a near lateral attitude.

It may appear difficult for the student to draw a diagram of the antero-posterior radiograph of the hip joint, but two curved lines give the true alignment of the bones (Fig. 102). The first line is the continuous curve of the anterior border of the ilium and the upper border of the neck of the femur. The second

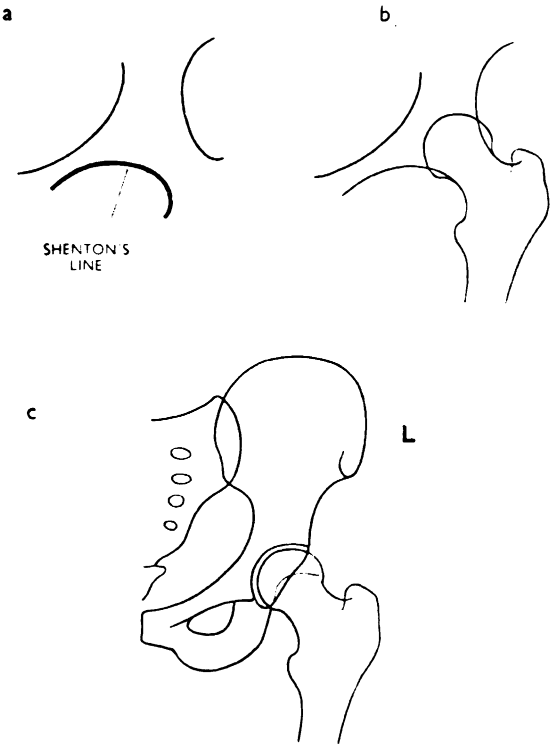


FIG. 102
Diagram of hip joint: antero-posterior view.

line is that of the upper border of the obturator foramen and the lower border of the neck. A third curve representing the pelvic brim can be added and from these preliminary lines the diagram can be completed.

The curve of the upper border of the obturator foramen and the lower border of the neck of the femur is known as Shenton's line and is important in the diagnosis of disease, as disruption of its continuity may indicate pathology at the hip joint.

Hip Joint : Lateral Radiograph (Fig. 103)

To bring the upper end of the femur into the lateral position, the trunk is turned obliquely to enable the leg to rotate outward through 90°.

At the hip joint the head of the femur is partly enveloped by the acetabulum. The joint space between the femoral head and the acetabular fossa is not

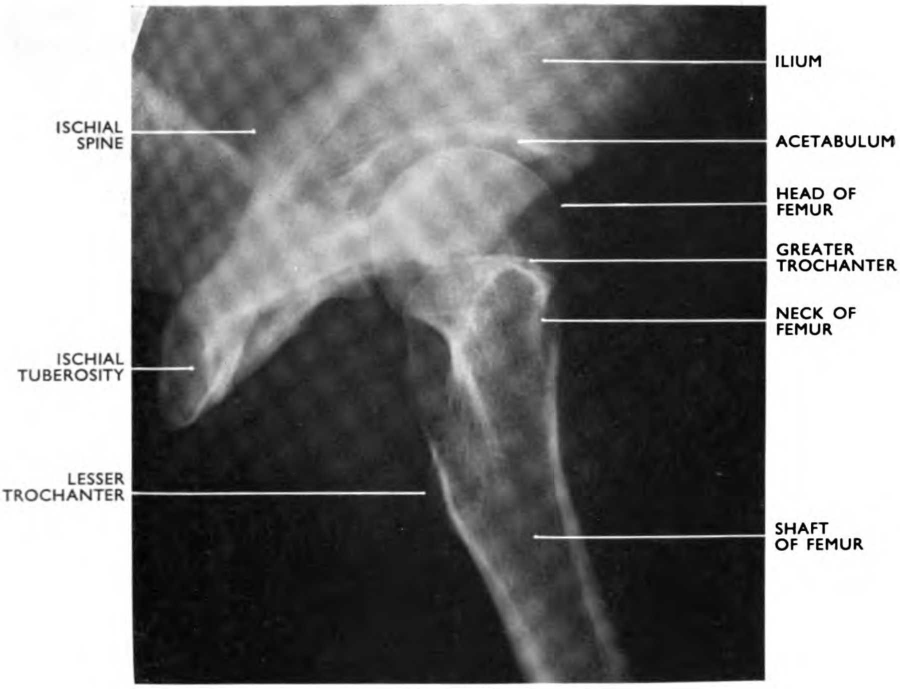


FIG. 103
Left hip joint: lateral radiograph.

uniform throughout: a short segment of increased space below the centre is the non-articular area of the fossa seen in profile.

The head, neck and greater trochanter are in line with the shaft of the femur, but the lesser trochanter protrudes slightly beyond the medial side of the shaft.

Two guide lines will be found of assistance in drawing a diagram of the lateral radiograph of the hip joint (Fig. 104). The first line drawn across the top of the diagram represents the general line of the hip bone. The second line drawn at not more than 75° to the first forms the line of the head, neck and shaft of the femur and will give approximately the correct relationship between the two bones. The acetabulum and femoral head are drawn at the junction of the two lines, and the neck, greater trochanter and shaft are drawn around the second guide line, remembering that the lesser trochanter projects medially.

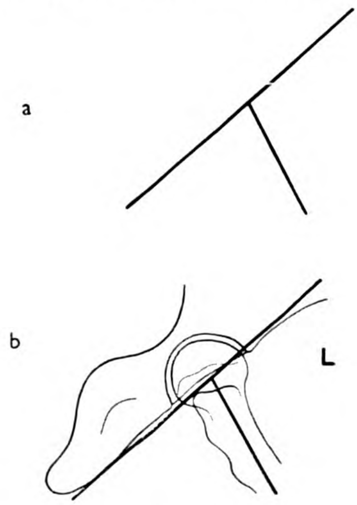


FIG. 104
Diagram of hip joint: lateral view.

Hip Joint : Lateral Radiograph for the Neck of the Femur (Fig. 105)

A fracture of the neck of the femur is often followed by a pinning operation: lateral radiographs will be required by the surgeon during the insertion of the pin.

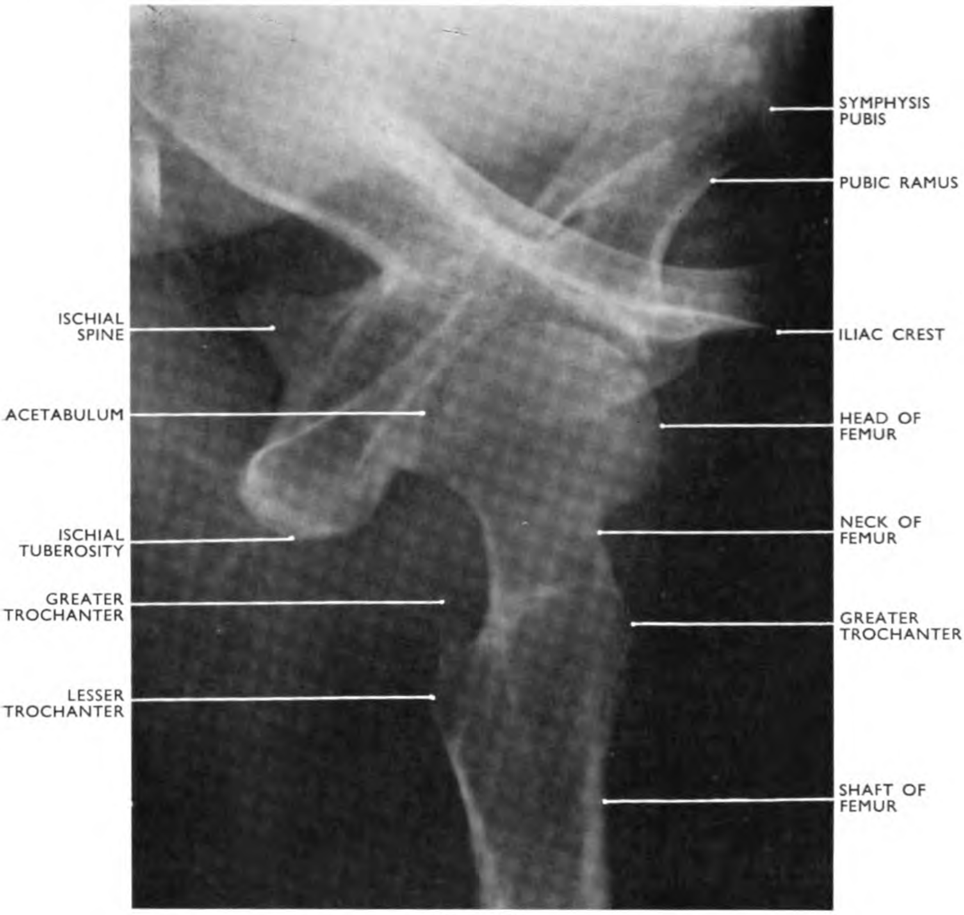


FIG. 105
Hip joint: lateral radiograph for neck of femur.

The lateral film in these cases must be taken with the patient in the supine posture. The X-ray tube is adjusted to direct the X-ray beam horizontally through the neck in an infero-superior or supero-inferior direction: only then may a clear image of the neck be obtained, free from the obscuring shadow of the greater trochanter. Compare Figure 103, the lateral radiograph of the hip joint, with Figure 105, the lateral radiograph of the neck of the femur.

THE PELVIS AS A WHOLE

The pelvis as previously stated is a strong and a complete bony ring. The two hip bones form the anterior and lateral walls and articulate with each

other in the midline anteriorly at the symphysis pubis. The wedge-shaped sacrum and the coccyx form the posterior wall and the sacrum articulates with the hip bones on either side at the sacro-iliac joint. The pelvis affords protection to the various organs of the lower abdominal and pelvic cavities, and also forms a strong ring to which many of the muscles of the abdomen, pelvis and lower limbs are attached. However, its main function is to transmit the weight of the head, trunk and upper limbs to the lower limbs.

In standing, the weight is transmitted through the upper part of the sacrum, sacro-iliac joints and strong medial borders of the ilia to the acetabula and thence to the heads of the femora: in sitting, the weight is transmitted from the medial borders of the ilia to the ischial tuberosities.

The **sacro-iliac joints** must therefore be joints of great strength and stability; these requirements are ensured by two factors—the shape of the joint and the surrounding ligaments. Although it is a synovial joint, the opposing joint surfaces are not smooth but are covered with small projections and depressions which fit into one another. This locking mechanism limits movement for the sake of stability. Furthermore, the joint surfaces are curved in an antero-posterior direction so that thrust from above cannot push the sacrum forward from between the hip bones.

An interosseus ligament of great strength is present between the sacrum and ilium behind the sacro-iliac joint, and this is further reinforced by dorsal and ventral sacro-iliac ligaments. However, a small degree of rotatory movement can take place at this joint, and this may be temporarily increased during pregnancy.

The pubic bones are joined in the midline by a cartilaginous disc (the symphysis pubis), strongly attached to the opposing bone surfaces. As in the sacro-iliac joint, movement is normally very slight, but may be increased in pregnancy.

A further group of ligaments, the vertebro-pelvic ligaments, also contribute to the stability of the lower spine and pelvis (Fig. 106). The lower part of the vertebral column has a double curve with the convexity forward in the lumbar region and a concavity forward at the sacrum. The lumbosacral joint tilts obliquely forward and downward: the iliolumbar ligaments passing between the transverse processes of the fifth lumbar vertebra and the upper parts of the ilia help to prevent the fifth lumbar vertebra from slipping forward on the sacrum. The sacrotuberous ligaments are attached at one end to the posterior iliac spines, sides of the sacrum and coccyx and at the other end to the ischial tuberosities. The sacrospinous ligaments, triangular in shape, are attached at their broad bases to the sacrum and coccyx and at their apices to the ischial spines. These two last pairs of ligaments prevent the sacrum and coccyx tilting downward through pressure on the lumbosacral joint.

The inguinal ligaments, passing between the anterior superior iliac spines and the pubic tubercles, do not directly contribute to the strength of the pelvis, but give attachment to some of the abdominal muscles. Above each ligament is the

inguinal canal and below is the femoral triangle, where the femoral vessels and nerves pass from the pelvis over the superior ramus of the pubis into the thigh.

The **pelvis** is divided into the false pelvis and the true pelvis by the brim or pelvic inlet.

The **true pelvis** is that part which lies below the pelvic brim. It is smaller

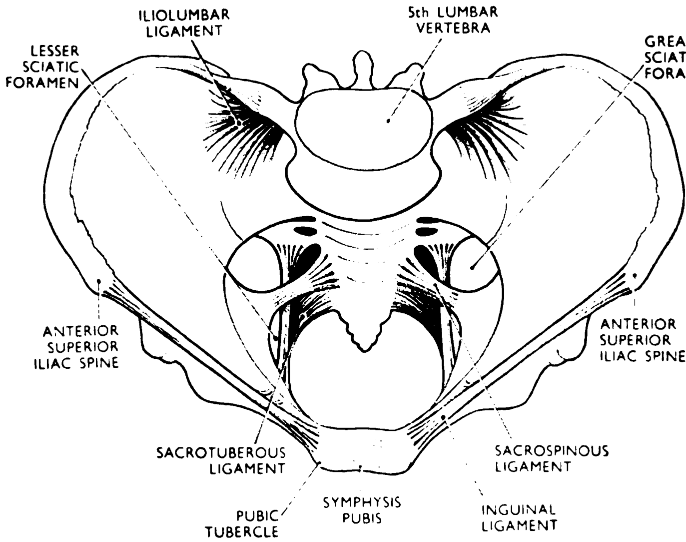


FIG. 106

Diagram of the pelvic ligaments.

than the false pelvis, forms the pelvic canal and contains the internal organs of reproduction, the urinary bladder and the lower parts of the alimentary tract (pelvic colon and rectum). The size and shape of the true pelvis in the female exert a great influence on the mechanism of labour.

The true pelvis can be divided into three parts :—

1. The **pelvic brim or inlet** (Fig. 107) is rounded and is formed from back to front by the promontory of the sacrum, the anterior surface of the lateral part (ala) of the sacrum, the iliopectineal line and the crest of the pubis.
2. The **pelvic cavity** (Fig. 108) is a curved canal bounded above by the pelvic inlet and below by the pelvic outlet. Its posterior length is considerably greater than its anterior length. It is formed by the pubic bones in front, the sacrum and coccyx behind and by the ilium and ischium at the sides.
3. The **pelvic outlet** (Fig. 109) is roughly diamond-shaped. It is formed in front by the rami of the ischium and pubis of both sides, at the sides by the ischial tuberosities and behind by the sacrotuberous ligaments and coccyx.

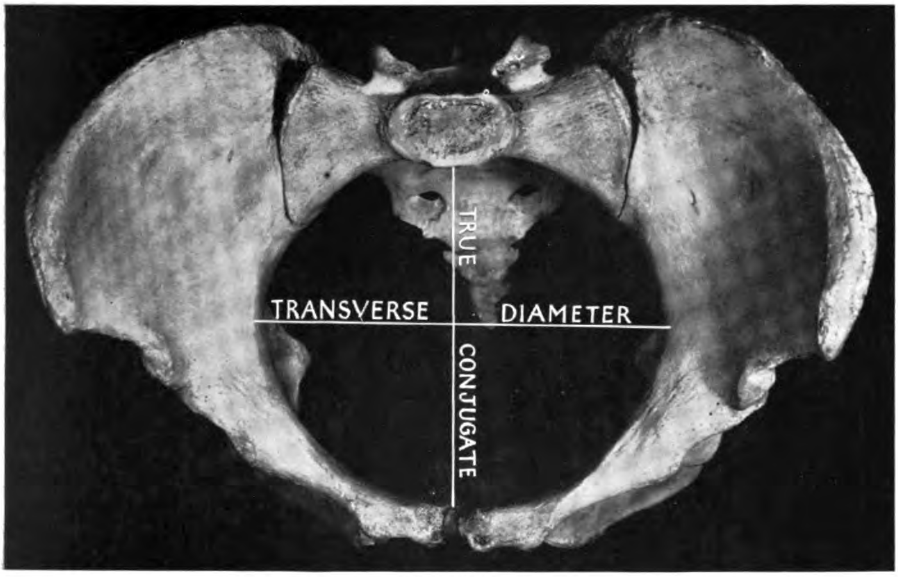


FIG. 107
The pelvic brim or inlet (dry bone).

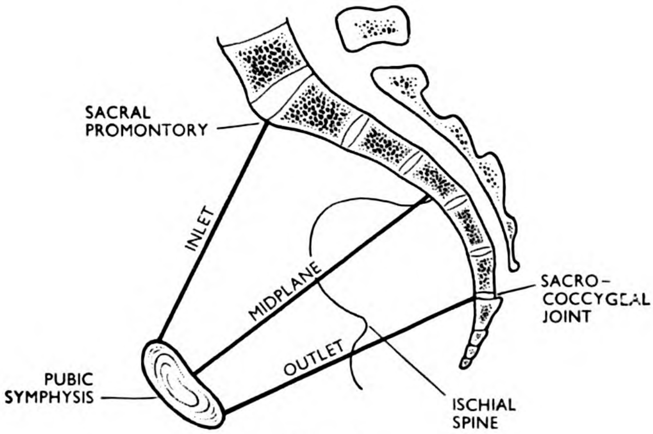


FIG. 108
Diagram of the pelvic cavity.

Three corresponding planes are described (Fig. 108) :—

1. The **plane of the inlet** is the most important. In the standing subject this plane is inclined at an angle of 55° to the horizontal, and is known as the inclination of the pelvis.
2. The **midplane** of the pelvic cavity lies on a line from the centre of the symphysis pubis to the centre of the third sacral vertebra.
3. The **plane of the outlet** extends from the lower border of the symphysis pubis to the apex of the sacrum.

In obstetric radiology measurements of the pelvic inlet, cavity and outlet are made with a view to assessing whether or not the dimensions and shape of the pelvic canal are favourable to the passage of the foetus. These measurements are usually taken in the three aforementioned planes. The most important measurements of the inlet and outlet are given below; they

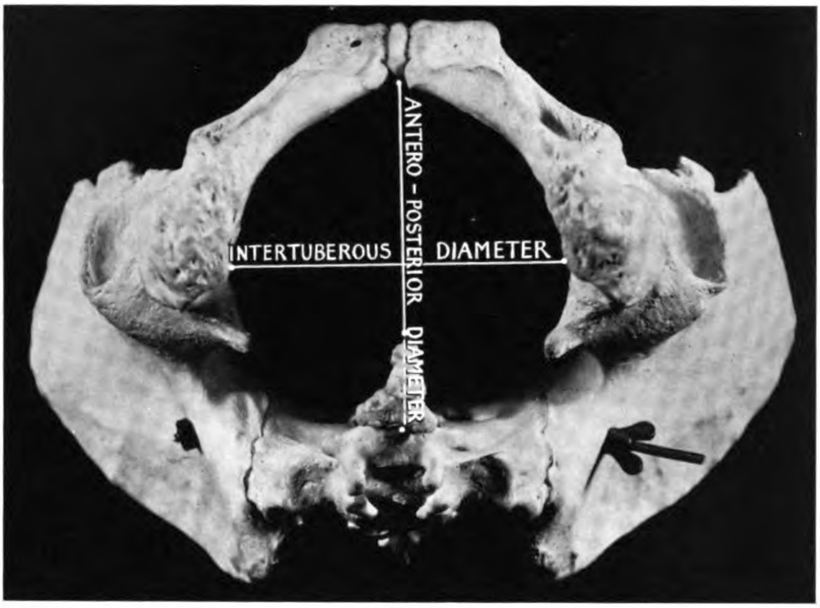


FIG. 109
The pelvic outlet.

represent an average of 509 female pelves examined by radiography (Ince and Young, 1940).

1. Plane of the Inlet

True Conjugate or Antero-posterior Diameter.—From the sacral promontory to the posterior edge of the upper surface of the symphysis pubis: 4·65 in. (11·83 cm.).

Transverse Diameter.—The widest transverse diameter of the pelvic brim: 5·12 in. (13·06 cm.).

2. Plane of the Outlet

Antero-posterior Diameter.—From the lower border of the symphysis pubis to the apex of the sacrum: 4·7 in. (11·97 cm.).

Transverse Diameter.—Between the inner surfaces of the ischial tuberosities: 4·28 in. (10·9 cm.).

The Pubic Arch in the female normally makes an angle (the subpubic angle) of 80° to 90°.

These measurements represent an average, but there are many variations in size and shape of the female pelvis. One of the best-known classifications is that of Caldwell, Moloy and their colleagues. In this classification four main types are recognised:—

	Shape of Inlet.	Midplane of Cavity.	Outlet.	
			Subpubic Angle.	Greater Sciatic Notch.
Gynaecoid (typical female type)	Rounded. Transverse diameter slightly greater than antero-posterior diameter	Side walls straight	Wide	Average to wide
Platypelloid (flat pelvis)	Antero-posterior diameter much shorter than transverse diameter	Side walls usually straight	Average to wide	Narrow
Anthropoid . .	Transversely narrow	Side walls straight or divergent	Average to wide	Wide
Android (typical male type)	Wedge-shaped or triangular	Side walls convergent	Narrow	Narrow

These four main types only form a basis of classification and there are many intermediate forms, *i.e.*, a pelvis may have a large rounded inlet (gynaecoid) with the cavity of the pelvis funnelling to a narrow outlet (android).

So far attention has been mainly directed to the female pelvis, since it is of particular interest to radiographers. The typical male pelvis differs in many respects; some of the differences relating to the true pelvis have been given in the table above (gynaecoid and android types), but the false pelvis also differs. Compared with the typical female pelvis, the typical male pelvis shows the following characteristics:—

1. The bones are larger and stronger, with well-defined ridges and impressions for muscle attachment.
2. The false pelvis is narrower.
3. The inlet of the true pelvis is smaller and triangular in shape.
4. The cavity of the true pelvis is longer, narrower and funnels towards the outlet.
5. The outlet of the true pelvis is narrower with a narrow pubic arch and a narrow greater sciatic notch.

RADIOGRAPHIC APPEARANCES OF THE PELVIS

Male Pelvis : Antero-posterior Radiograph (Fig. 110)

This antero-posterior radiograph is taken with the subject in the supine posture, and it provides a good general view of the main bony structures of the pelvis as a whole. The iliac crest curves round in a wide sweep to end in front

at the anterior superior iliac spine; thence the anterior border of the ilium descends to the anterior inferior iliac spine, which is situated just above the acetabulum. As the sacro-iliac joints are oblique to the X rays, the shadows of the ala of the sacrum and the iliac bones overlap and no clear joint space is visible throughout; a narrow curved zone of decreased bone density marks the anterior lip of the joint, and medial to the lower part of this zone a small portion of the posterior margin of the joint is visible. The ischial tuberosity

FIG. 110
Male pelvis: antero-posterior radiograph.

is a prominent bony feature below the acetabulum. The medial surfaces of the bodies of the pubic bones face one another at the symphysis pubis and are separated by a cartilaginous disc which does not cast a shadow. The obturator foramina are slightly oblique to the X rays, since in the living subject they face forward, outward and downward; the bony margins are formed by the pubic and ischial bones. The medial margins of the rami of the ischial bones and the descending rami of the pubic bones converge to an apex at the symphysis and the angle so formed is called the subpubic angle. The medial border of the ilium and the upper borders of the superior ramus and body of the pubis are seen to form the lateral and anterior margins of the true pelvis; the posterior margin, which is formed by the upper border of the first sacral vertebra, is not clearly defined as the sacrum is oblique to the X rays. The lower part

of the sacrum is obscured by intestinal gas shadows and the coccyx is partly hidden by the superimposed symphysis pubis.

Female Pelvis : Antero-posterior Radiograph (Fig. 111)

Some of the main differences between the male and female pelvis can be seen by comparing Figure 110 with Figure 111. The bones of the female pelvis are lighter in structure; the false pelvis and transverse diameter of the true pelvis are broader. The symphysis pubis is shallower and the subpubic angle

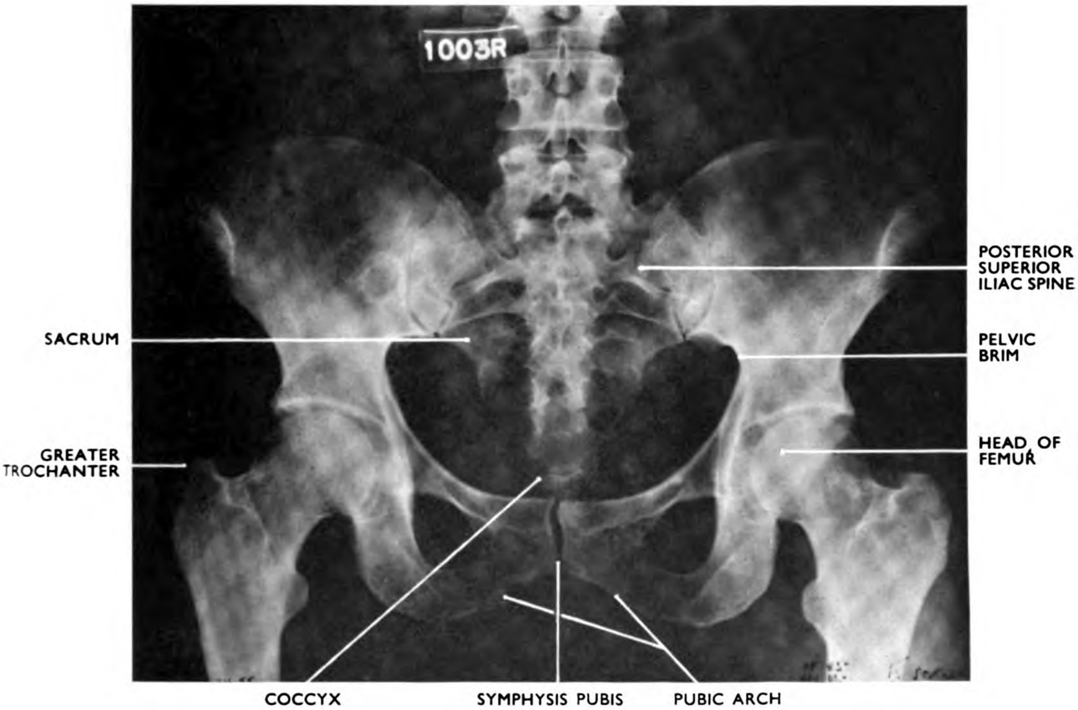


FIG. 111
Female pelvis: antero-posterior radiograph.

is greater in the female; the depth of the true pelvis is also shorter. It is important to remember that the inclination of the pelvis will be about 55° to the vertical in the supine posture and that a foreshortened image of the pelvic inlet will be obtained. The radiograph is therefore of limited value in assessing the shape and size of the true pelvis owing to distortion.

Diagram of the Antero-posterior Radiograph of the Pelvis (Fig. 112)

Figure 112 gives a method of constructing a diagram of the pelvis in five stages. It is recommended that the student should use such a system as diagrams are frequently required.

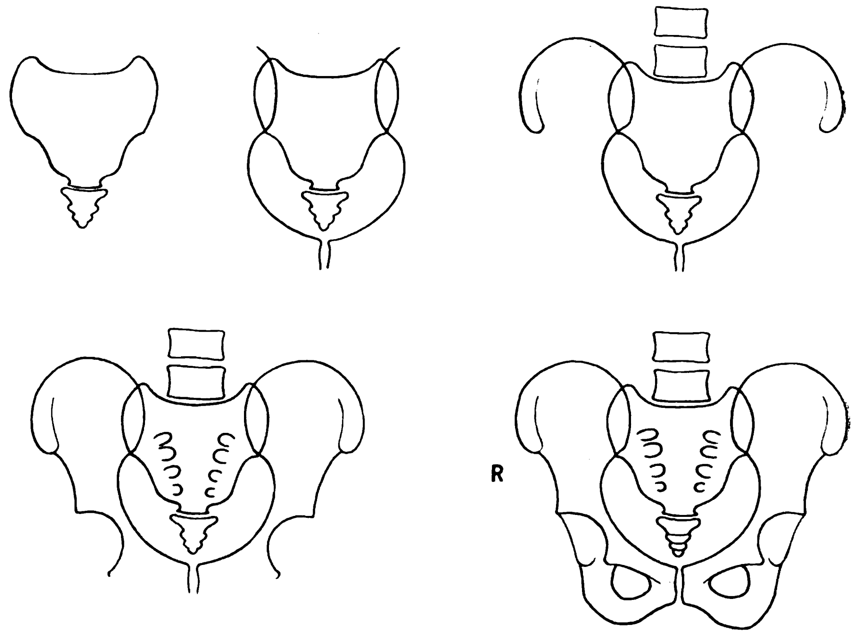


FIG. 112
Diagram of the antero-posterior radiograph of pelvis.

Pelvis : Lateral Radiograph (Fig. 113)

For a lateral radiograph of the pelvis the X rays must penetrate a great depth of body tissue and if a high voltage apparatus is not available, a short focus-film distance will be used. In this particular radiograph, taken with short distance technique, an enlarged image of the hip bone farthest from the film is obtained and the shadow of the iliac crest of this side is considerably higher than that on the side nearest the film.

The fourth and fifth lumbar vertebrae, the lumbosacral joint and the sacrum are clearly demonstrated. The anterior concavity of the sacrum and coccyx is evident and the divisions between the individual sacral vertebrae well marked. The rectum lies immediately in front of the sacral concavity and is visible solely because of the gas contained within. The greater sciatic notches are seen a short distance in front of the junction of the second and third sacral vertebrae. The ischial spines at the lower edge of the greater sciatic notches are almost obscured by soft tissue shadows, but the ischial tuberosities are clearly visible, as are the rami of the pubic bones which form the anterior margins of the obturator foramina. Bony detail of the heads of the femora and acetabula is poor, but the joint space outlines their position. The superimposed shadows of the upper ends of the femoral shafts partly obscure the ischial bones and the inferior rami of the pubic bones, but anteriorly the symphysis pubis is visible as a thick bony lip.

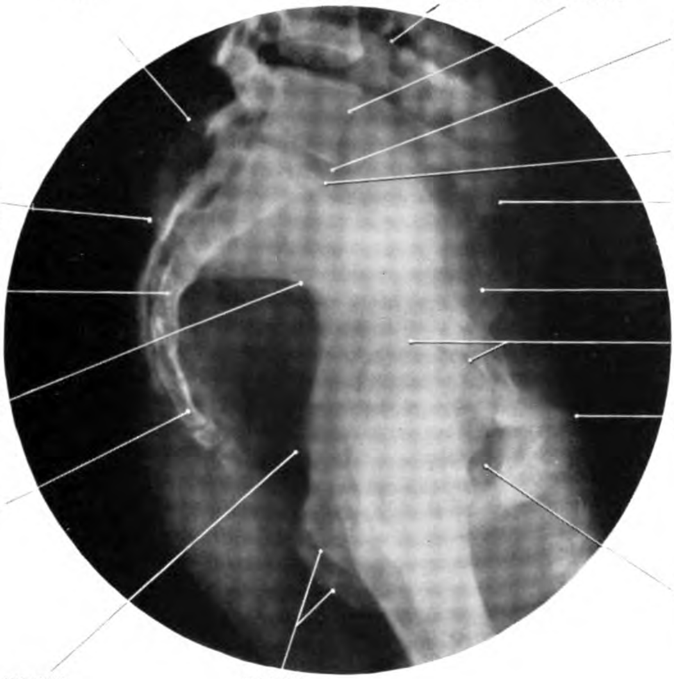


FIG. 113
Pelvis: lateral radiograph.

Sacro-iliac Joints : Antero-posterior Radiograph (Fig. 114)

The general plane of the sacro-iliac joint is directed forward and laterally so that it is oblique to the X rays and a clear joint space is not visible. In this radiograph there is an overlap of the ala of the sacrum and the ilium, although the posterior superior iliac spines can be clearly seen. The anterior margin of the joint occupies only the lower half of the narrow space between the lateral edge of the ala and the ilium; a strong interosseous ligament connects the two bones above. A portion of the posterior part of the joint is often visible medial to the anterior margin of the joint space, as on the right side in this radiograph.

Sacro-iliac Joints : Oblique Radiograph (Fig. 115)

A clear view of a sacro-iliac joint may be obtained if the trunk is rotated 15° to bring the plane of the joint under examination as near vertical as possible. The irregularity of the joint space is clearly visible and it is often impossible to demonstrate the whole joint space on one radiograph.

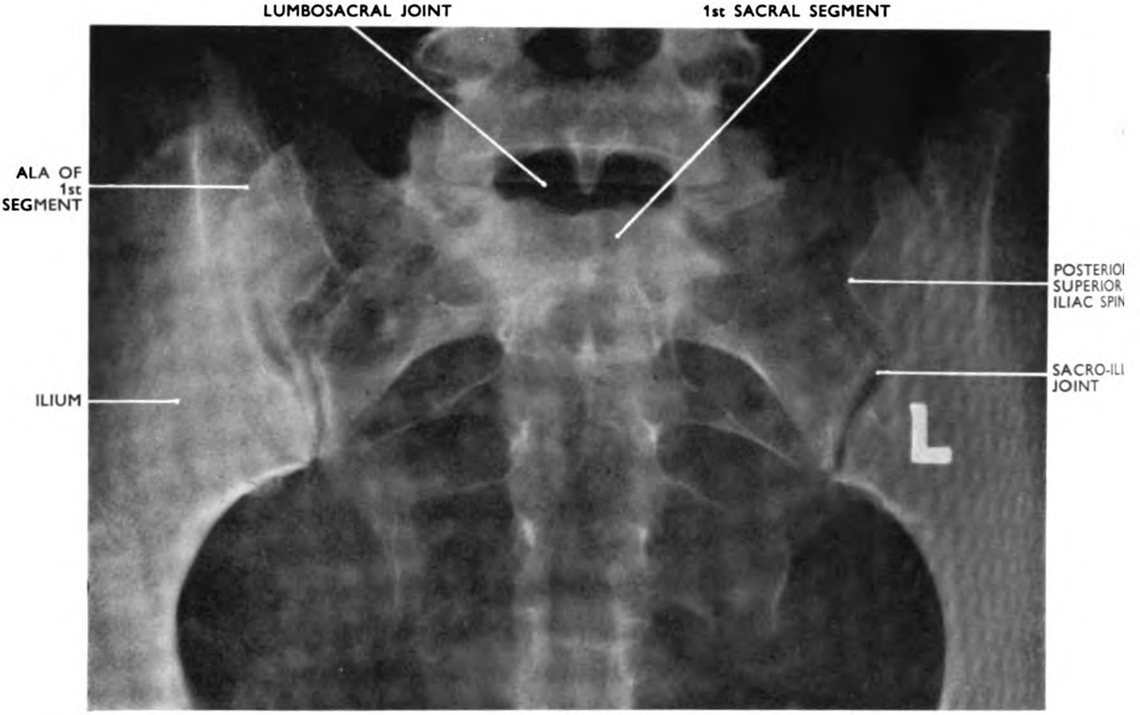


FIG. 114
Sacro-iliac joints: antero-posterior radiograph.

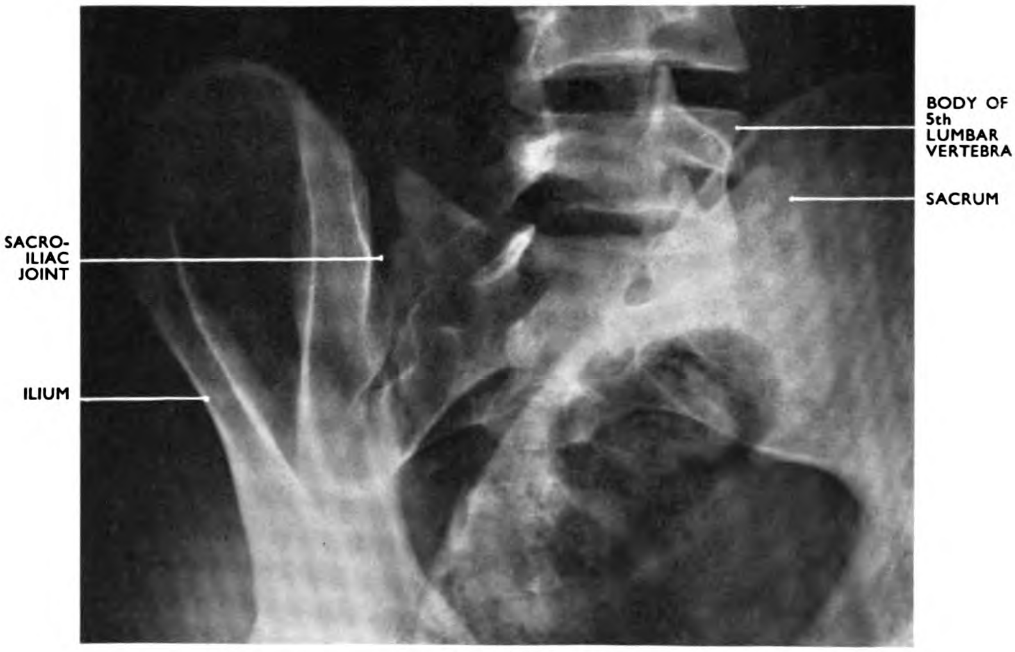


FIG. 115
Right sacro-iliac joint: oblique radiograph.

Pelvis : Supero-inferior Radiograph for the Pelvic Inlet (Fig. 116)

This radiograph is taken with the patient seated above the film and positioned so that the pelvic brim is parallel to the film. The anatomical surface markings used to ensure correct positioning are the pubic crest in front and a point midway between the spinous processes of the fourth and fifth lumbar vertebrae behind. When these two surface markings are equidistant from the film, the brim of the true pelvis is parallel to the film and its true shape will be correctly recorded. As the pelvic brim is some distance above the film an enlarged

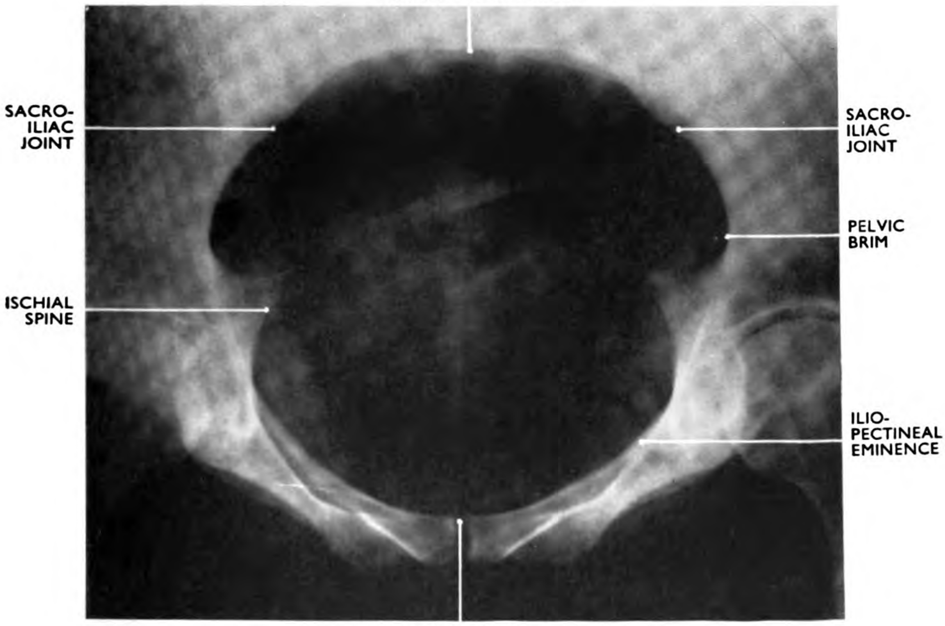


FIG. 116
Pelvic inlet : Supero-inferior radiograph.

image is produced, but if the brim to film distance and the focus-film distance are known, its true size can be calculated.

The radiograph is that of the inlet of a typical female type (gynaecoid). It is rounded with the transverse diameter slightly greater than the antero-posterior diameter (true conjugate). The sacral promontory produces a slight indentation in the midline posteriorly and a short distance on either side the anterior margins of the sacro-iliac joints are visible. If positioning of the patient is correct, the superior and inferior rami of the pubis are usually superimposed, so that the obturator foramen is completely hidden. The ischial spines project medially into the pelvic cavity but they are situated at the lower level of the pelvic outlet.

Pelvis : Supero-inferior Radiograph for the Pelvic Outlet and Pubic Arch (Fig. 117)

It will be remembered that the rami of the ischial bones and the inferior rami of the pubic bones converge on the lower margin of the symphysis pubis, and that the angle so formed is called the subpubic angle. To measure this angle accurately its plane must be parallel to the film ; this can be achieved if the patient sits on the film and stoops forward, so that the symphysis pubis

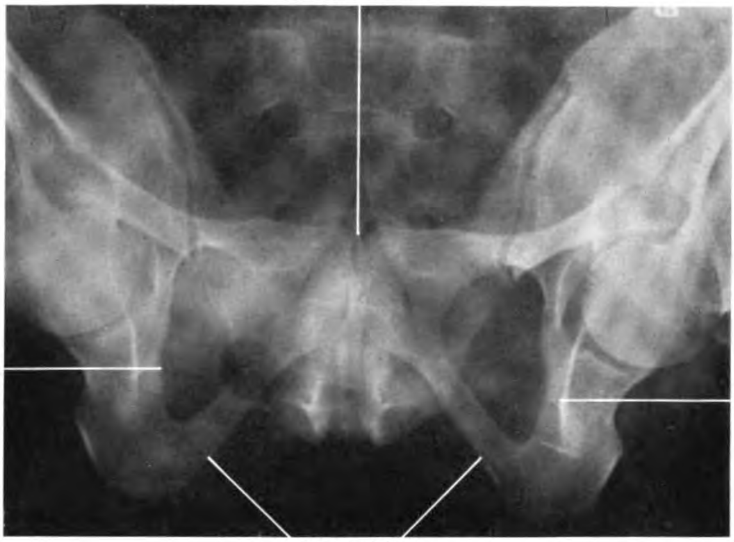


FIG. 117
Pelvic outlet : supero-inferior radiograph.

and ischial tuberosities are equidistant from the film. On a radiograph taken with the patient so positioned, the symphysis pubis and the ischial and pubic bones are clearly visible and measurement of the subpubic angle is simply effected. Beyond the lateral border of the obturator foramen is a denser line of bone cast by the pelvic surface of the ischial tuberosity ; the distance between these lines is the transverse diameter of the pelvic outlet (intertuberous diameter). Behind the symphysis pubis is an enlarged image of the sacrum, with the foreshortened shadow of the coccyx below. The femora are in a flexed position and the femoral heads and acetabula are partly visible.

Pelvis : Lateral Radiograph for the Pelvic Canal (Fig. 118)

A lateral radiograph of the pelvis supplies three essential measurements :—

1. The antero-posterior diameter of the inlet (true conjugate). [Sacral promontory to the posterior margin of the upper surface of the symphysis pubis.]

2. The midplane diameter. [Midpoint of the anterior surface of the third sacral vertebra to the centre of the posterior surface of the symphysis pubis.]
3. The antero-posterior diameter of the outlet. [Apex of the sacrum to the lower margin of the posterior surface of the symphysis pubis.]

The subject-film distance again causes an enlarged radiographic image, but provided that the focus-film distance and the median plane of the pelvis-film

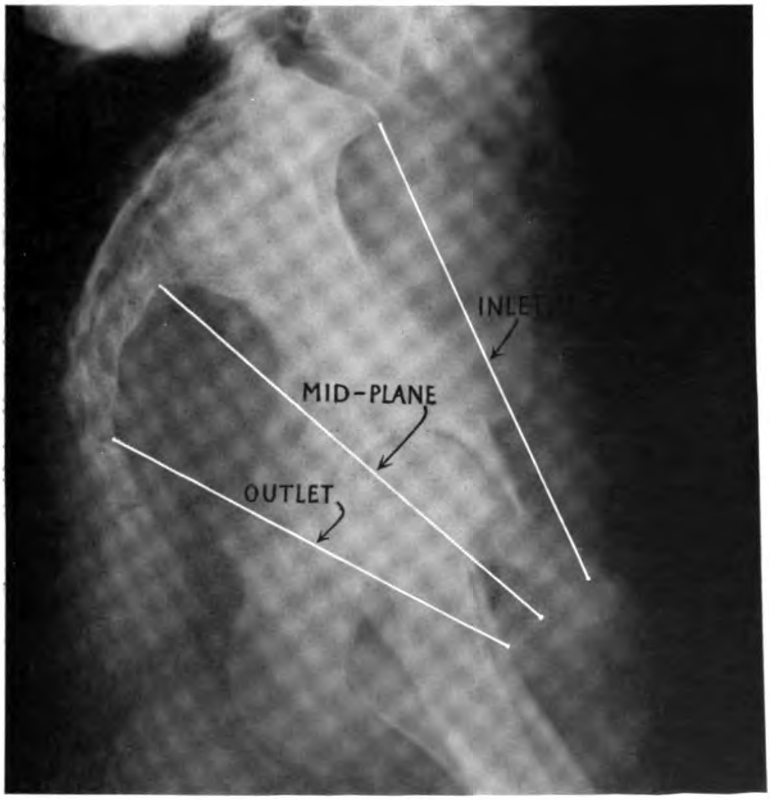


FIG. 118
Pelvic canal: lateral radiograph.

distance are known, the true measurements can be simply estimated. Alternatively, a metal rule notched at centimetre or inch intervals can be placed against the cleft of the patient's buttocks, *i.e.*, in the median plane; the scale will then be magnified equally with all other distances in the median plane and a direct reading can be made from the radiograph.

CHAPTER V

VERTEBRAL COLUMN

THE vertebral column forms the central bony axis of the body. It consists of thirty-three individual bones called vertebrae, placed one upon another. The vertebrae are divided into five groups, each group showing certain modifications of a general structural pattern: the groups are cervical, thoracic, lumbar, sacral and coccygeal. There are seven vertebrae in the cervical region, twelve in the thoracic, five in the lumbar, five in the sacral and four in the coccygeal region. The sacral and coccygeal vertebrae fuse to form the sacrum and coccyx about puberty and are referred to as the fixed vertebrae, whereas the other remain as movable vertebrae throughout life.

A **typical vertebra** (Figs. 119 and 120) consists of an anterior segment, the body, and a posterior segment, the vertebral arch: the two segments together enclose the vertebral foramen, in which the spinal cord lies. The body of one vertebra is joined to the bodies of the vertebrae above and below by fibrocartilaginous intervertebral discs.

The **body** is shaped like a short cylinder and is formed of spongy bone thinly covered by compact bone. The anterior surface is convex and is slightly roughened: the posterior surface is slightly concave and is perforated by one or two openings for veins. The upper and lower surfaces are flat and roughened.

The **vertebral arch** consists of the pedicles and laminae and supports seven processes—two transverse, four articular and one spinous.

The **pedicles** are short rounded processes which project backward from either side of the posterior surface of the body.

The **laminae** are flat plates of bone, which project backward and medially from the ends of the pedicles to meet and fuse in the midline.

The **vertebral foramen** is formed anteriorly by the posterior surface of the body, laterally by the pedicles and posteriorly by the laminae.

The **transverse processes** project laterally from the junction of the pedicles and laminae and give attachment to ligaments and muscles.

The **articular processes** are arranged in pairs—a superior and an inferior process on each side of the arch. The superior articular processes bear facets which face backward and articulate with the forward facing inferior facets of the vertebra above.

The **spinous process** projects backward in the midline at the junction of the laminae and acts as a lever for the muscles of the back.

The **intervertebral foramina** lie between the pedicles of adjacent vertebrae and transmit the spinal nerves. The concavities above and below the pedicles

are called the vertebral notches and the notches of two adjacent vertebrae combine to form an intervertebral foramen. Whilst the vertebrae, with

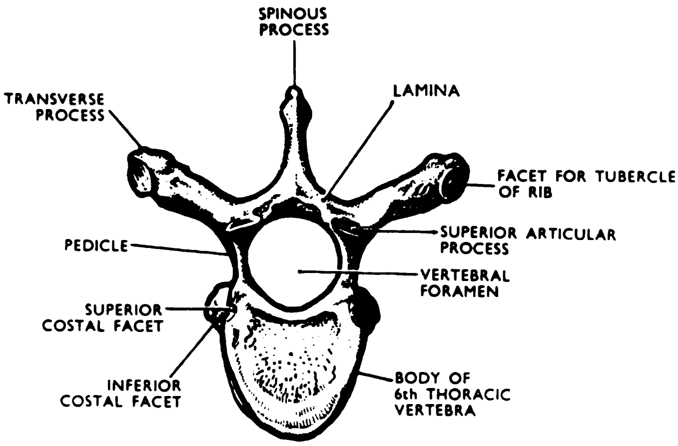


Fig. 119
Thoracic vertebra: superior aspect.

certain exceptions, conform to this general plan, the vertebrae of one particular region show certain characteristic features. A typical vertebra is situated in

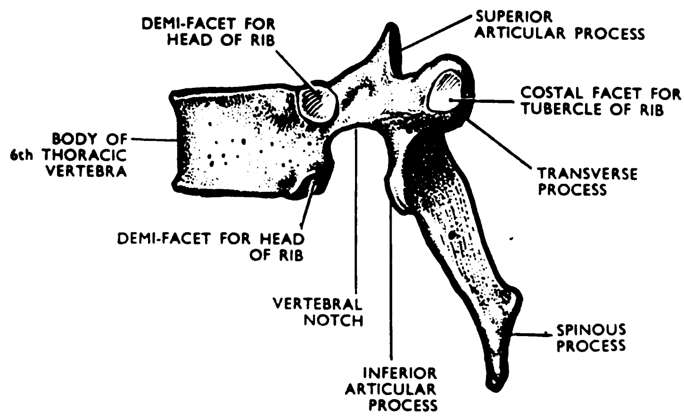


Fig. 120
Thoracic vertebra: lateral aspect.

the middle of each group; the upper and lower vertebrae of that group are modified to provide a gradual transition from one region to another.

CERVICAL VERTEBRAE

The cervical vertebrae are the smallest of the movable vertebrae. The first, second and seventh have special features which distinguish them from the others.

The body of a typical cervical vertebra (Figs. 121, 122 and 123) is small and is wider from side to side than from back to front. The lateral margins of the upper surface are upturned and articulate with the lateral margins of the vertebra above; the small synovial joints so formed are found only in the cervical region.

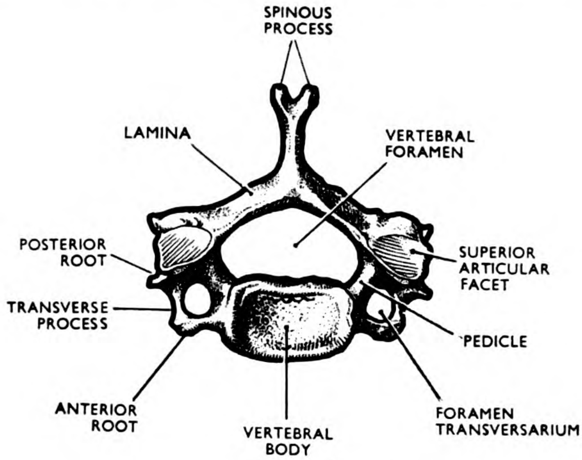


FIG. 121
Fifth cervical vertebra: superior aspect.

The **vertebral arch** as a whole is large in comparison with the body and the vertebral foramen is also large and triangular. The **transverse processes** are each pierced by a foramen (the foramen transversarium) for the passage of the vertebral vessels. The posterior root of the transverse process represents the

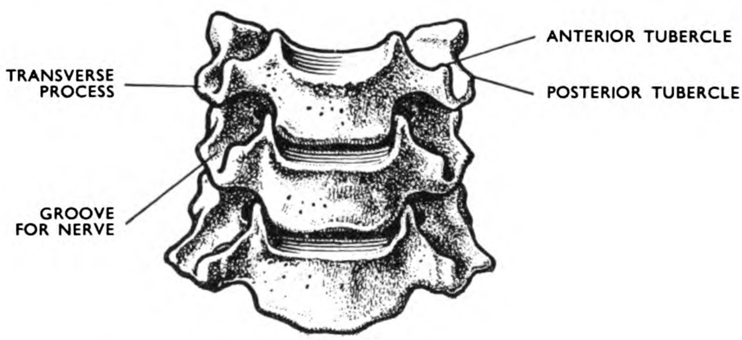


FIG. 122
Fourth to sixth cervical vertebrae: anterior aspect.

true transverse process, whilst the anterior root represents the costal element, which becomes separate and forms a rib in the thoracic region; each root ends in a tubercle. The **articular processes** form a bony pillar on each side, at the junction of the pedicles and laminae, behind the transverse processes. The articular facets are oval and flat; the superior facets face upward and

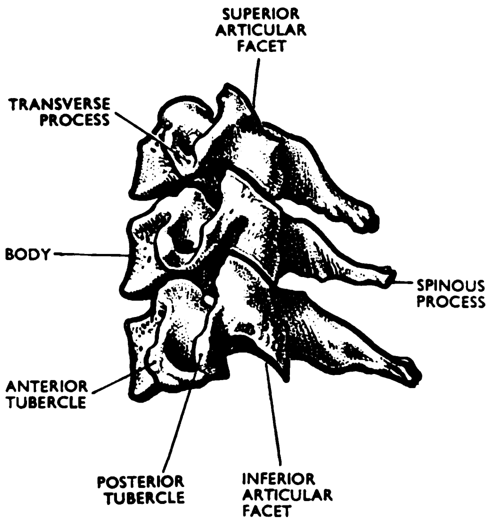


FIG. 123
Fourth to sixth cervical vertebrae: lateral aspect.

backward, and the inferior facets downward and forward. The **spinous processes** are short and bifid. The intervertebral foramina in the cervical spine face forward and outward at an angle of 45° to the median plane.

Atlas (Figs. 124 and 125)

The name atlas is given to the first cervical vertebra because it supports the head. It has no body and no spinous process and is shaped like a ring.

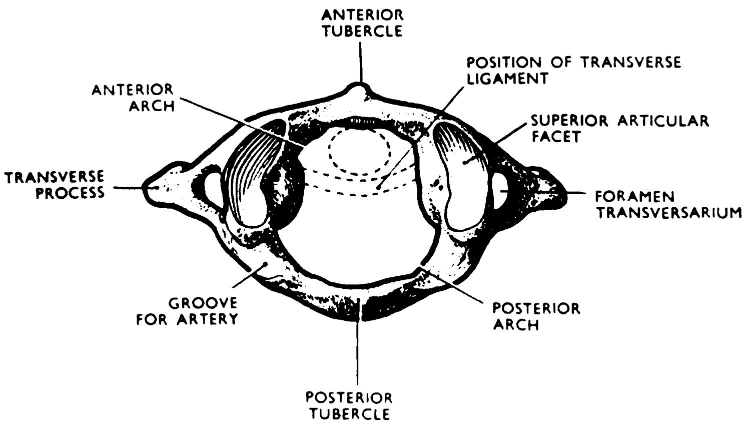


FIG. 124
Atlas: superior aspect.

It consists of an anterior and a posterior arch and two lateral masses.

The anterior arch is the smaller part of the ring: a small projection, the **anterior tubercle**, is present on its anterior surface, whilst on the posterior

surface is a small facet for articulation with the odontoid process of the second cervical vertebra (axis).

The **posterior arch** forms the larger part of the ring: on its posterior surface is the posterior tubercle which represents a much reduced spinous process. The obliquely set **lateral masses** have articular facets on their upper and lower surfaces. The upper facets are oval and concave and articulate with the occipital condyles of the skull to form the atlanto-occipital joints. The inferior facets are round and flat and articulate with the superior facets of the second cervical vertebra (axis).

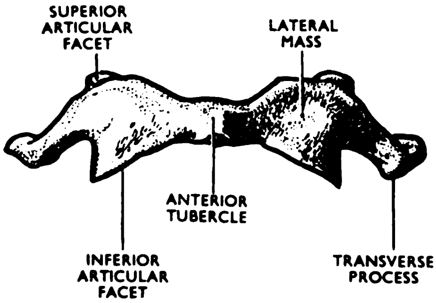


FIG. 125
Atlas: anterior aspect.

On the inner side of each lateral mass is a prominent tubercle to which the transverse ligament is attached. This ligament divides the ring into two parts; the anterior smaller part is occupied by the odontoid process of the axis, whilst the spinal cord occupies the larger posterior part.

The perforated transverse processes are longer than those of the other cervical vertebrae and act as levers for the rotatory muscles of the head. Behind the articular facets on the upper surface of the atlas are shallow grooves for the vertebral arteries which enter the cranial cavity through the foramen magnum.

Axis (Figs. 126 and 127)

The second cervical vertebra or axis consists of a body and a vertebral arch. Its chief feature is the **odontoid process** which projects upward from the upper surface of the body; this process articulates with the posterior surface of the anterior arch of the atlas and is held in position by the transverse ligament of the atlas; it forms the pivot around which the atlas and head rotate, and represents the body of the atlas fused with that of the axis.

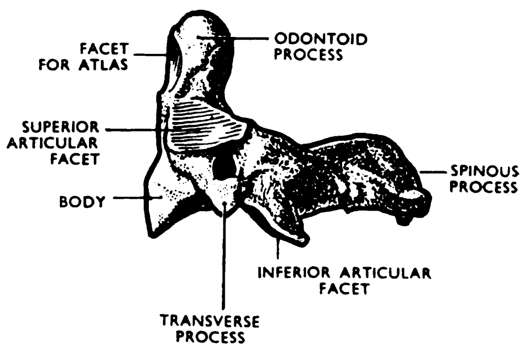


FIG. 126
Axis: lateral aspect.

The spinous process is large and bifid and is a prominent feature in radiographs of the cervical spine. The superior articular facets are borne on the lateral part of the body and adjacent part of the pedicles, and articulate with the inferior facets on the lateral masses of the atlas. The transverse processes are small.

Seventh Cervical Vertebra

This vertebra has a prominent spinous process which ends in a single tubercle and which can be felt easily through the skin. The transverse process is large; the anterior part (the costal element) may develop as a cervical rib. The foramen transversarium is small and may even be absent.

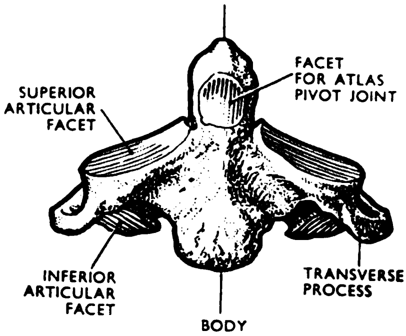


FIG. 127
Axis: anterior aspect.

THORACIC VERTEBRAE

The twelve thoracic vertebrae can be distinguished by the presence of small articular facets on the lateral sides of the bodies and, with the exception of the eleventh and twelfth vertebrae, on the transverse processes: these facets articulate with the heads and tubercles of the ribs. The first, ninth, tenth, eleventh and twelfth vertebrae differ slightly from the others and will be considered separately.

The **body** of a typical thoracic vertebra (Figs. 119 and 120) is heart-shaped. The height and width are about equal, but the bodies are a little deeper behind than in front—a factor which is responsible for the normal slight anterior concavity of the thoracic spine as a whole. The bodies decrease slightly in

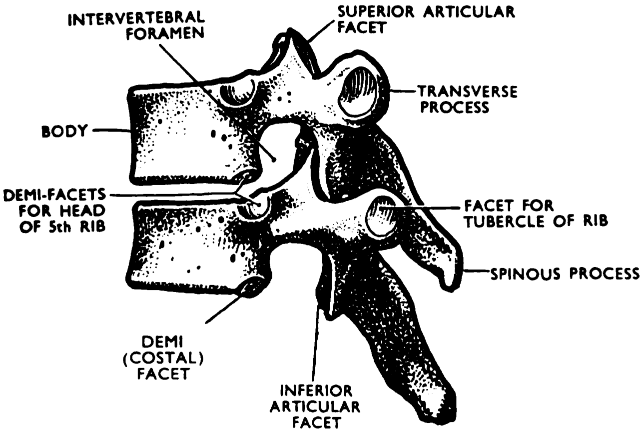


FIG. 128
Fourth and fifth thoracic vertebrae: lateral aspect.

size from the first to the third vertebra, and then progressively increase in size to the twelfth. On either side of the body are two half or demi-facets, one above and one below, for articulation with the heads of the ribs: each rib therefore articulates with two vertebral bodies (Fig. 128).

The **pedicles** are short and project backward from the body to meet the short deep **laminae**; the **vertebral foramen** is circular and smaller than in the cervical region.

The **transverse processes** are thick and strong; on the anterior surface of each extremity is a facet for articulation with the tubercle of a rib.

The **articular processes** are almost vertical: the superior facets face backward and the inferior facets forward.

The **spinous processes** are long and slender and are directed downward and backward.

The **intervertebral foramina** are formed by a relatively deep inferior vertebral notch, and open laterally in front of the transverse processes.

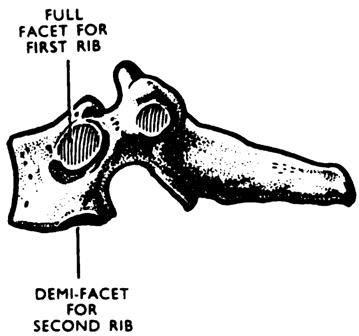


FIG. 129A
First thoracic vertebra: lateral aspect.

First Thoracic Vertebra (Fig. 129A)

The body has on each side a whole superior articular facet for the head of the first rib, and a demi-facet below for the head of the second rib.

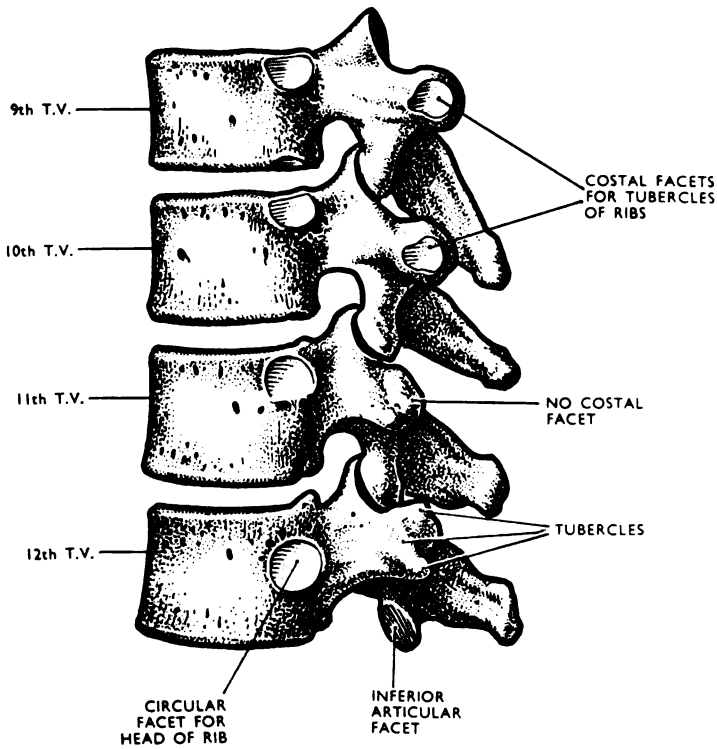


FIG. 129B
Ninth to twelfth thoracic vertebrae: lateral aspect.

Ninth Thoracic Vertebra (Fig. 129B)

The body has demi-facets above: the lower facets are very small or absent.

Tenth Thoracic Vertebra (Fig. 129B)

Complete superior facets are present: the lower facets are absent.

Eleventh and Twelfth Thoracic Vertebrae (Fig. 129B)

Complete articular facets are present on the sides of the bodies: no facets are present on the transverse processes which are small. The bodies are large and the superior articular facets are beginning to face laterally as in the lumbar region.

LUMBAR VERTEBRAE

The five lumbar vertebrae have to support considerable weight and are therefore larger and strongly built. The fifth lumbar vertebra differs slightly

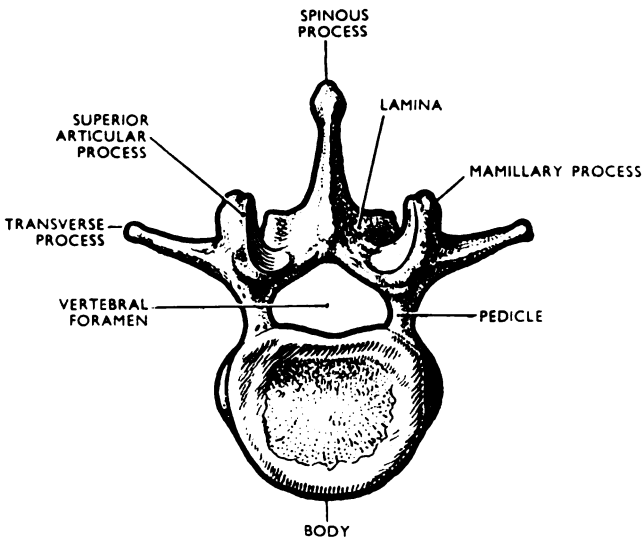


FIG. 130
Third lumbar vertebra: superior aspect.

from the others. The **body** of a typical lumbar vertebra (Figs. 130 and 131) has wide kidney-shaped upper and lower surfaces, and is a little deeper in front than behind.

The **pedicles** are short and thick. The **vertebral foramen** is relatively small and triangular in shape.

The **transverse processes** are long and thin and project laterally, slightly upward and backward.

The **spinous processes** are thick, broad and horizontal in direction.

The **articular processes** are large: the superior facets face backward and inward and the inferior facets forward and outward.

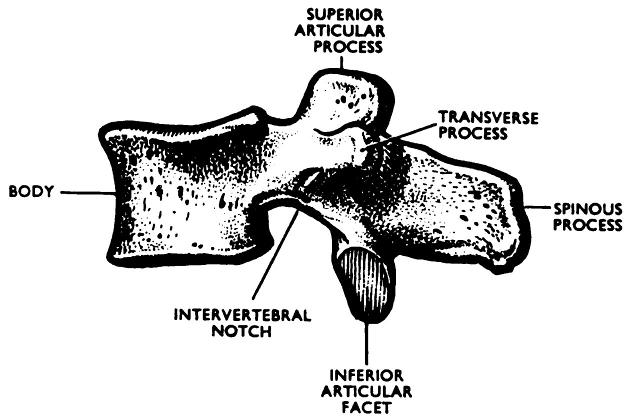


FIG. 131
Third lumbar vertebra: lateral aspect.

Fifth Lumbar Vertebra

This vertebra forms the lumbosacral angle with the sacrum: the body is appreciably deeper in front than behind. The transverse process is short and arises from the pedicle and also from the side of the body.

SACRUM

Five sacral vertebrae (Figs. 132, 133 and 134) which diminish in size from above downward, fuse in adolescence to become a single wedge-shaped bone with a marked anterior concavity. The base articulates with the fifth lumbar vertebra at an angle to form the lumbosacral joint: the apex articulates with the coccyx and the sides bear the auricular surfaces for articulation with the iliac bones.

The basic components of a typical vertebra are still present in a sacral segment, but in a modified form. The individual bodies can be identified; the part lateral to the anterior sacral foramina is called the lateral mass and consists of fused transverse processes and costal elements, and the sacral canal is a continuation of the vertebral canal.

The **base** of the sacrum is formed by the upper surface of the first sacral vertebra. The anterior margin of the upper surface of the first vertebral body has a well-marked edge, the sacral promontory, which is an important landmark in obstetrics. Behind the body, the short pedicles and laminae enclose the triangular sacral canal: the spinous process is small and is known as the spinous tubercle. The superior articular facets face inward and backward and articulate with the inferior facets of the fifth lumbar vertebra.

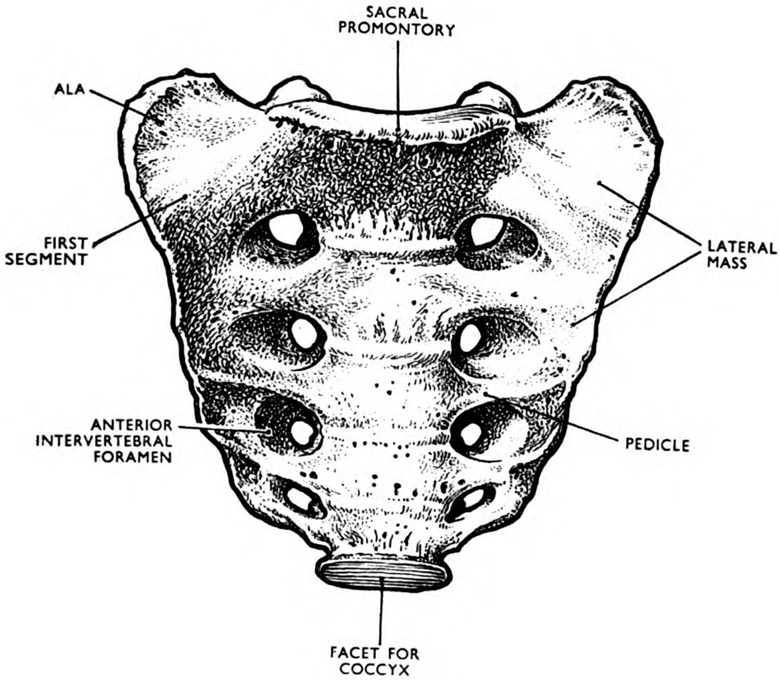


Fig. 132
Sacrum: anterior or pelvic surface.

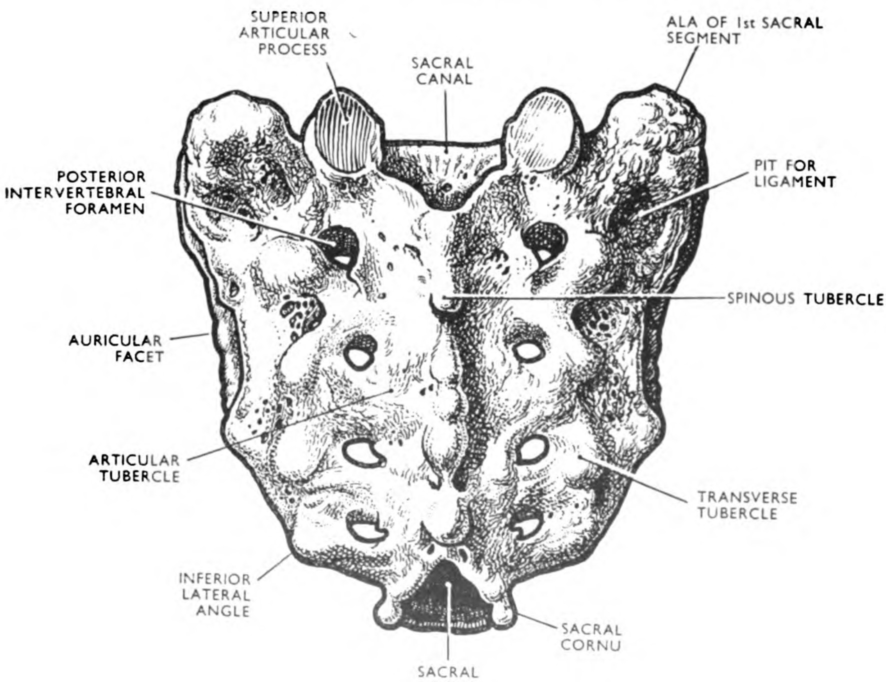


Fig. 133
Sacrum: dorsal surface.

The **anterior or pelvic surface** of the sacrum is concave (Fig. 132). Four transverse ridges are present in the centre of the bone and mark the site of fusion of the individual sacral bodies. The ridges terminate laterally at the anterior intervertebral (pelvic sacral) foramina, of which there are four on each side: the foramina transmit the anterior primary rami of the sacral nerves from the sacral canal to the pelvis. The lateral mass of the sacrum, as previously stated, lies lateral to the foramina. The upper part of the lateral mass is large and is formed by the upper three sacral vertebrae, and on its

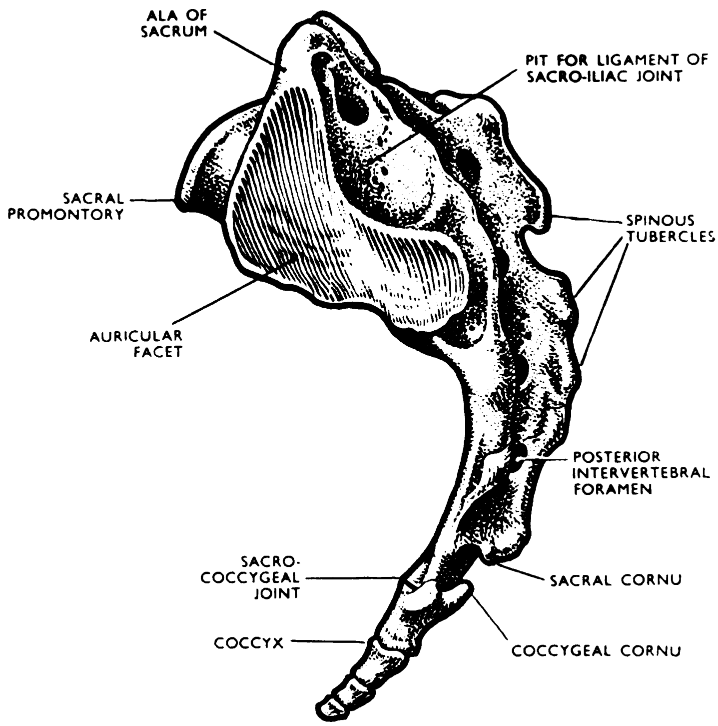


FIG. 134
Sacrum and coccyx: lateral aspect.

lateral aspect is the auricular surface for articulation with the iliac bone. The upper surface of this lateral mass is called the ala of the sacrum.

The **dorsal surface** of the sacrum is convex (Fig. 133). Extending down the centre of the bone is a prominent bony crest, bearing four spinous tubercles, which represent the spinous processes. Below the last spinous tubercle the dorsal surface of the sacral canal is deficient—this small gap is called the sacral hiatus. On either side of the central crest are four posterior intervertebral (dorsal sacral) foramina which transmit the posterior primary rami of the sacral nerves from the sacral canal. Of the articular processes only the superior articular processes of the first sacral segment bear articular facets: the articular processes below fuse and are represented by small bony prominences known

as articular tubercles which are medial to the dorsal foramina. The inferior articular processes of the last sacral segment form small bony projections, the sacral cornua, on either side of the sacral hiatus.

The **lateral surface** of the sacrum is wide above and narrow below (Fig. 134). The auricular surface for articulation with the ilium is situated toward the front of the upper part, and behind the articular facet the bone surface is rough for ligamentous attachment. The lower part of the lateral surface is thin, and gives attachment to the sacrotuberous ligament.

The **apex** of the sacrum bears a small articular facet for the coccyx.

COCCYX

This small triangular bone (Fig. 135) consists of four segments usually fused together.

The first segment possesses a body with rudimentary transverse processes and superior articular processes (the coccygeal cornua). The remaining segments consist of rudimentary bodies only, which decrease in size from above down.

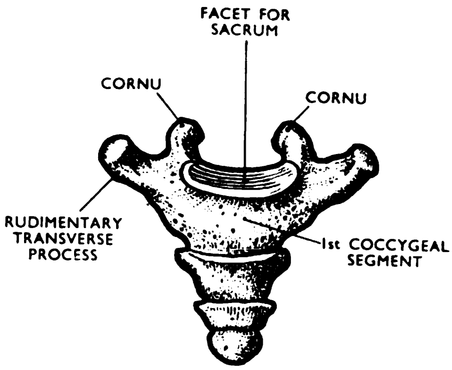


FIG. 135
Coccyx: anterior aspect.

Articulated Vertebral Column

The intervertebral joints of the movable region of the vertebral column consist of fibro-cartilaginous joints between the vertebral bodies and synovial joints between the vertebral arches. The one exception is the articulation between the atlas and the axis which consists of synovial joints only. The joints are reinforced by a number of ligaments.

The **joints of the bodies** consist of fibro-cartilaginous intervertebral discs which lie between the opposing surfaces of the bodies. The disc is composed of outer rings of fibro-cartilage (the annulus fibrosus) surrounding a small gelatinous centre (the nucleus pulposus), and is firmly adherent to the thin layers of hyaline cartilage which cover the upper and lower surfaces of the bodies. The disc allows a small degree of movement between adjacent bodies. The depth of the disc varies from one region of the column to another and from one part of a disc to another: those in the cervical and lumbar regions are thicker, particularly at the front of the disc, to allow more freedom of movement and to help create the forward convexity of the column in these two regions.

The joints are strengthened by anterior and posterior longitudinal ligaments, which are attached not only to the anterior and posterior surfaces of the bodies but also to the discs; these ligaments extend from the first cervical vertebra to the upper sacral segment.

The **joints of the vertebral arches** are those between the articular processes. They are synovial joints and are of the plane type with capsular ligaments: these ligaments are particularly loose in the cervical region where movement is greatest. Between the atlas and axis there is no intervertebral disc, but one pivot joint and two plane joints. The pivot joint between the anterior arch of the atlas and the odontoid process of the axis allows rotation of the head. The plane joints are those between the facets on the lateral masses of the atlas and the superior facets of the axis.

The joints receive support from a number of ligaments:—

1. The **supraspinous and interspinous ligaments** connect the spinous processes and extend from the seventh cervical vertebra to the sacrum.
2. The **ligamentum nuchae** is a broad midline fibro-elastic membrane which extends between the occipital region of the skull and the spinous processes of the cervical vertebrae. It represents fused supraspinous and interspinous ligaments.
3. The **intertransverse ligaments** pass between the transverse processes.
4. The **ligamenta flava** are attached to the laminae of adjacent vertebrae. They are composed of elastic tissue; they prevent overflexion of the vertebral column, and assist the column to return to the vertical position after flexion.

Movements of the Vertebral Column

The movements of the vertebral column are flexion, extension, side flexion, circumduction and rotation. Whilst movement between any two adjacent vertebrae is small, the total effect over the length of the movable regions of the column is considerable. Mobility is related to the thickness of the intervertebral disc, the direction of the articular processes and the ligaments: it is greatest in the cervical and lumbar regions and least in the thoracic region.

During flexion, the anterior part of the disc is compressed: the posterior ligaments (the posterior longitudinal, the supraspinous and infraspinous ligaments and the ligamenta flava) are stretched.

Extension, which is not a marked movement, is limited by the anterior longitudinal ligament and by contact of the spinous processes.

Lateral flexion is limited by the resistance of the ligaments and muscles. Rotation results in twisting of the intervertebral discs and, whilst of small degree between any two adjacent vertebrae, is considerable over the length of the movable column.

In the cervical region, the downward and backward plane of the articular facets permits free extension and flexion. Lateral flexion and rotation are combined movements.

Movements in the thoracic region are limited, especially in the upper part, so as not to interfere with respiratory movements. The almost vertical plane

of the articular facets severely limits flexion and extension, although rotation is comparatively free. Lateral flexion is limited mainly by the ribs and sternum.

In the lumbar region, flexion, extension and side flexion are free, but rotation is very limited.

Curves of the Vertebral Column (Fig. 136).

The vertebral column of the foetus has two primary curves, thoracic and

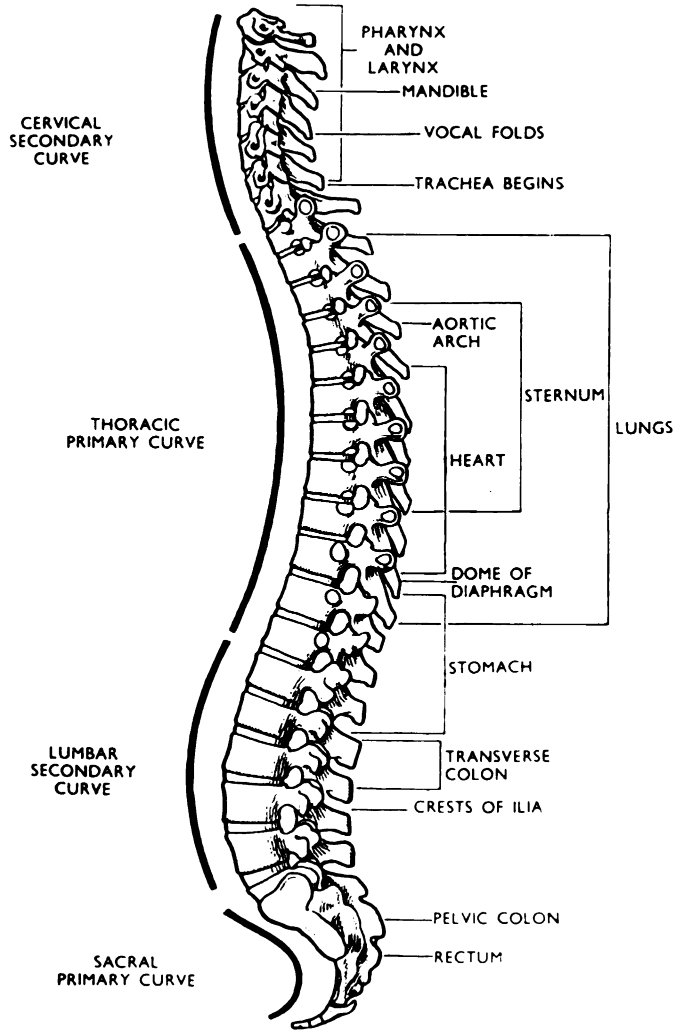


FIG. 136
Diagram of whole vertebral column, showing the primary and secondary curves to the left and to the right the approximate levels of other body structures which have to be considered during radiography of the column.

pelvic (sacrum and coccyx); both are concave forward. The cervical and lumbar curves are secondary and are convex forward. The cervical curve

develops during the first year of life when the child learns to hold up its head. The lumbar curve develops in the second year when the child begins to walk.

The diagram (Fig. 137, A to C) compares the curvature of the vertebral column

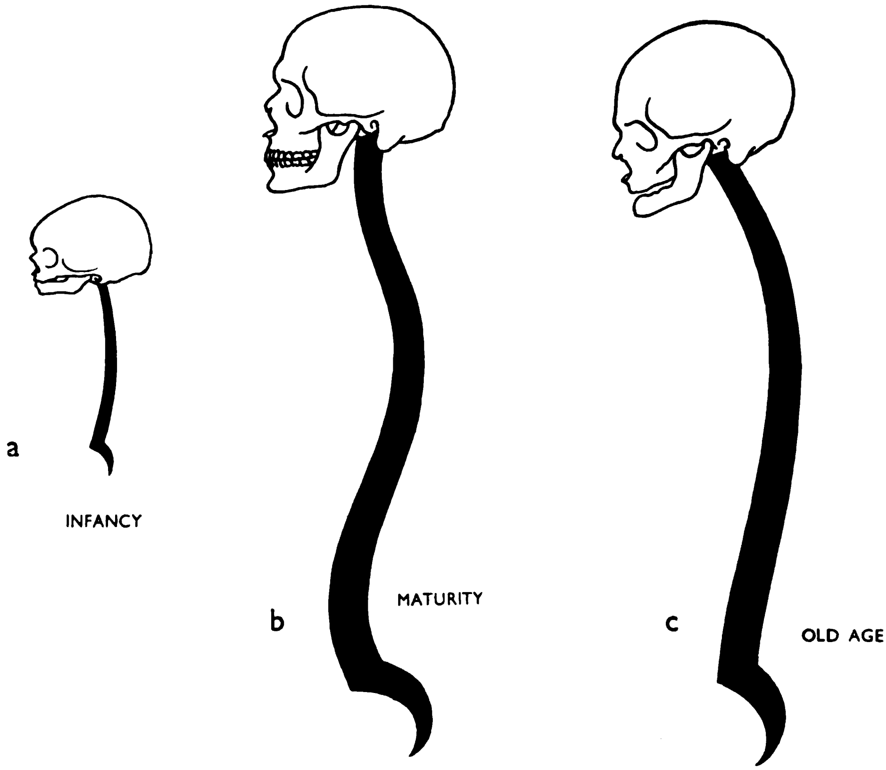


FIG. 137
Diagrams of the vertebral column showing change of curvature over the life span.

over the normal life span. In the infant, two primary curves are present: in the adult the four curves are fully developed, whilst in old age the secondary curves tend to disappear.

Spinal Cord

In the early stages of foetal life the vertebral column and the spinal cord are of equal length, but owing to the more rapid growth of the vertebral column, the cord terminates at the level of the third lumbar vertebra at birth, and at the level of the intervertebral disc between the first and second lumbar vertebrae in the adult. The spinal cord occupies only part of the vertebral canal and is surrounded by three membranes—the pia mater, the arachnoid and the dura mater. These membranes help to suspend the cord in the vertebral canal and to protect it, whilst allowing a small degree of movement to take place during movements of the vertebral column. The arachnoid membrane is separated

from the pia mater, which closely invests the cord, by the subarachnoid space: this space contains cerebrospinal fluid and is continuous with the cavities of the ventricles of the brain where the fluid is secreted.

Two areas of enlargement of the cord are present, the cervical and the lumbar: they correspond to the areas of origin of the large nerves of the upper and lower limbs respectively. The lower end of the cord tapers to a conical extremity, the conus medullaris, which usually lies at the level of the intervertebral disc between the first and second lumbar vertebrae: a thin thread, the filum terminale, which does not contain nervous tissue, extends from the apex of the conus medullaris to be attached to the first segment of the coccyx. Although the cord ends high up in the lumbar region, the subarachnoid space extends down to the second sacral segment; puncture of the membranes in the lower lumbar region for the purpose of examining the cerebrospinal fluid may therefore be undertaken without risk of damage to the cord.

Thirty-one pairs of spinal nerves arise from the spinal cord, roughly corresponding to the number of vertebrae, and leave the vertebral canal through the intervertebral foramina. As the spinal cord is considerably shorter than the vertebral column, successive spinal nerves pass more and more obliquely downward to reach their respective intervertebral foramina. Below the termination of the cord these nerves form a large sheaf called the cauda equina on account of its supposed resemblance to a horse's tail.

RADIOGRAPHIC APPEARANCES OF THE VERTEBRAL COLUMN

Radiography of the Cervical Vertebrae

Owing to the presence of the mandible, antero-posterior radiography of the cervical vertebrae is undertaken in two stages. The first film for the upper two vertebrae is taken through the open mouth, and the second film to show the lower vertebrae is taken with the mouth closed, but using a low centring point in order to project the shadow of the mandible as high as possible.

The difference in radiographic density between these two areas is largely due to the large spinous process of the axis vertebra. In the lateral position all seven vertebrae are clearly demonstrated on one film.

Atlas and Axis: Antero-posterior Radiograph (Fig. 138)

When the head is correctly adjusted the curve of the upper dental arch overshadows the reverse curve of the occipital bone in the radiograph: the deeper downward curve of the lower dental arch allows the shadows of the first two vertebrae to appear between the upper and lower teeth. Part of the body of the third vertebra with its small spinous process may also be visible, especially in the edentulous subject.

The odontoid process projects upward from the body of the axis and lies between, but not in contact with, the lateral masses of the atlas. The anterior and posterior arches of the atlas are superimposed and are visible as a faint shadow extending across the odontoid process between the lateral masses. The tip of the odontoid process is seen to project a short distance above the level of the arches of the atlas. The unusually long transverse processes of the

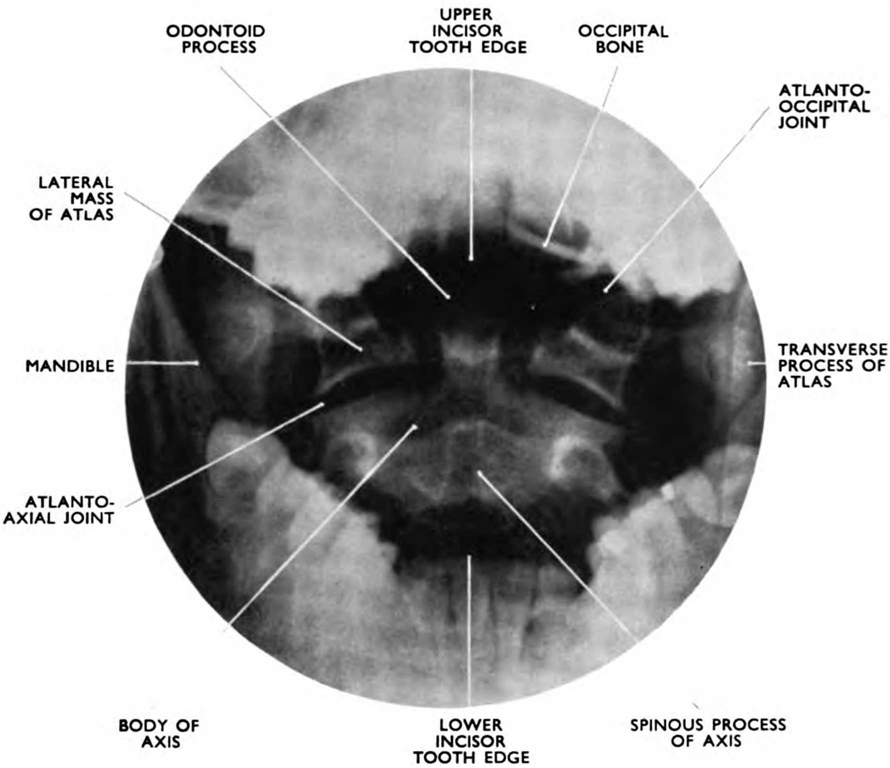


FIG. 138
Atlas and axis: antero-posterior radiograph.

atlas project laterally from the lateral masses and on the radiograph only just clear the superimposed shadows of the inner margins of the mandible.

The two plane joints between the atlas and the axis are clearly demonstrated and are seen to be inclined downward and outward: below the superior articular facets of the axis are the half-rounded denser shadows of the pedicles, here seen almost end-on. Between the pedicles a curvilinear line marks the upper margin of the laminae which meet in the midline, where the spinous process is visible as a roughly oblong shadow.

In a simple diagrammatic representation of this radiograph Figure 139, A, gives the curves of the encircling structures and Figure 139, B, the position of the atlas and axis between them.

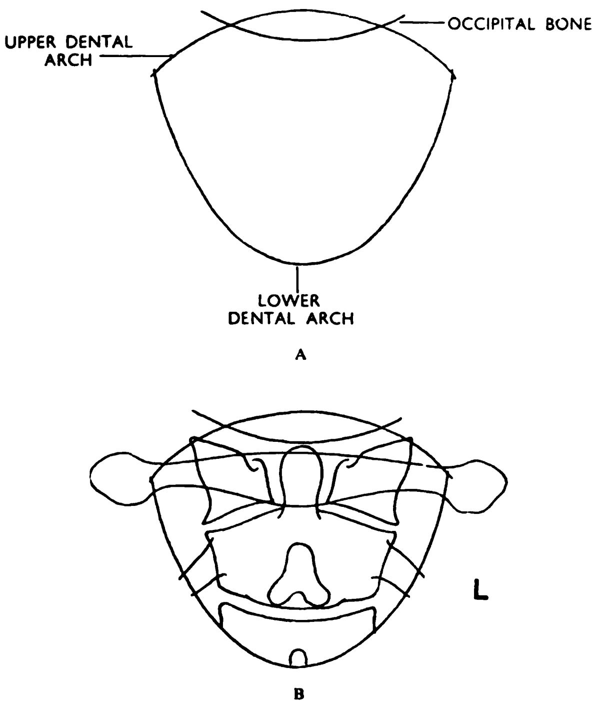


FIG. 139
Atlas and axis: diagram of antero-posterior radiograph.

Cervical Vertebrae (3rd to 7th): Antero-posterior Radiograph (Fig. 140)

The shadows of the mandible and occipital bone coincide to obscure the atlas and axis, but the lower five cervical vertebrae are clearly visible.

The slightly concave upper surfaces of the bodies are seen to be accentuated by the lips on the lateral margins, with corresponding bevels on the margins of the opposing inferior surfaces of the bodies above: this marginal articulation lies in front of the intervertebral foramen, and arthritic changes may therefore cause irritation of the spinal nerve. Superimposed in the midline of the vertebral bodies are the spinous processes which are, with the exception of that of the seventh vertebra, bifid. The combined shadows of the transverse processes and articular pillars are short and relatively deep, although the transverse processes of the seventh cervical vertebra are long. The overall configuration of the seventh vertebra is very similar to that of the first thoracic vertebra.

The dark shadow of the air-filled larynx lies over the bodies of the upper vertebrae, and sometimes the vestibular and vocal folds can be identified. Below the level of the fifth vertebra the transradiant air-filled trachea is clearly outlined.

FIG. 140
Third to seventh cervical vertebrae: antero-posterior radiograph.

Cervical Vertebrae : Lateral Radiograph (Fig. 141)

The slight anterior convexity of the cervical spine is clearly demonstrated on this radiograph.

The atlanto-occipital joints are obscured by the superimposed mastoid processes, but the atlas is clearly identifiable with the anterior and posterior tubercles seen in profile. The odontoid process of the axis is visible immediately behind the anterior arch of the atlas with which it articulates: the transverse ligament, which lies on its posterior surface and secures it in position, does not cast a shadow. The spinous process of the axis is long and massive, since it serves as a site of attachment for muscles which control the movements of rotation and extension of the head on the vertebral column.

The upper surfaces of the bodies of the third to seventh vertebrae are flat from behind forward, but, as has already been seen, they are slightly concave

from side to side: the lower surfaces of the bodies are gently concave. The shadows of the transverse processes are superimposed on the bodies and detail is lacking. The short pedicles project backward from the upper margins of the bodies and end at the articular pillars, which are composed of the superior and inferior articular facets: the plane of the joints is seen to be directly downward and backward. The laminae appear short owing to their

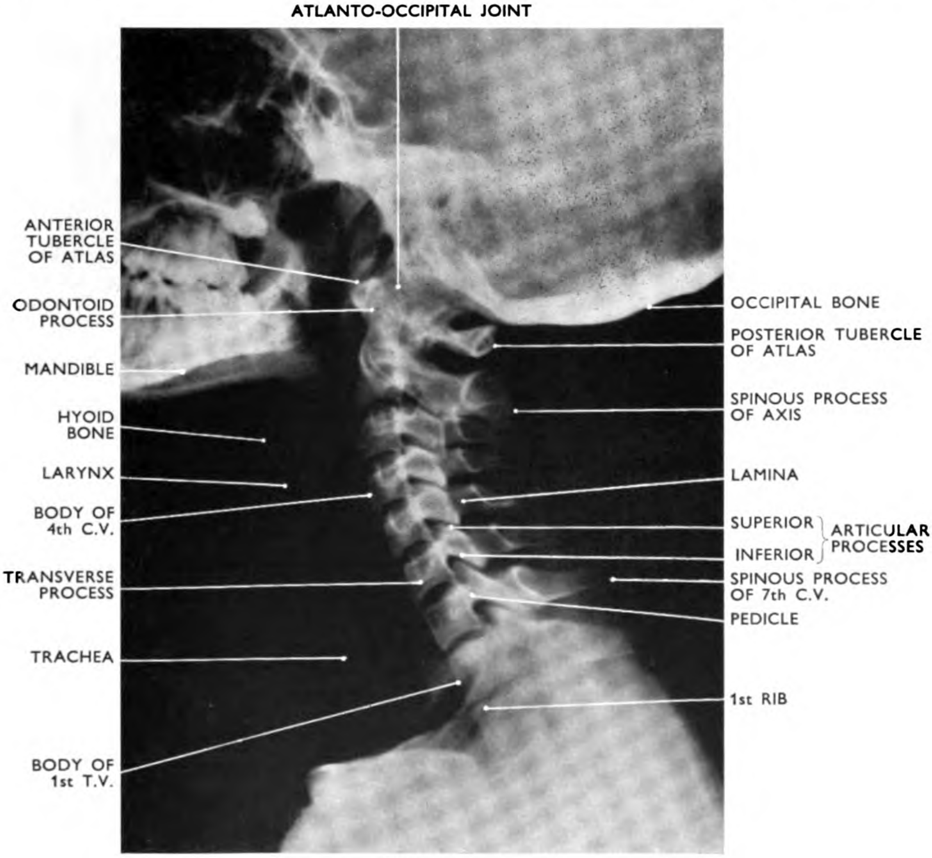


FIG. 141
Cervical vertebrae: lateral radiograph.

obliquity and end in spinous processes which are short, with the exception of that of the seventh vertebra, which is long and can be felt through the skin. The intervertebral discs appear as transradiant spaces between the bodies and their depths are uniform throughout the cervical spine, although it will be noticed that the disc space between the seventh cervical and the first thoracic vertebrae is normally a little shallower. In front of the upper three vertebrae the ramus of the mandible is clear of the bodies since the chin is raised—an important point to be remembered during positioning for this radiograph. The shadows of the air-filled pharynx, larynx and trachea lie immediately in front of the vertebral bodies.

A method of constructing a diagram of the lateral radiograph is given in Figure 142, A to C.

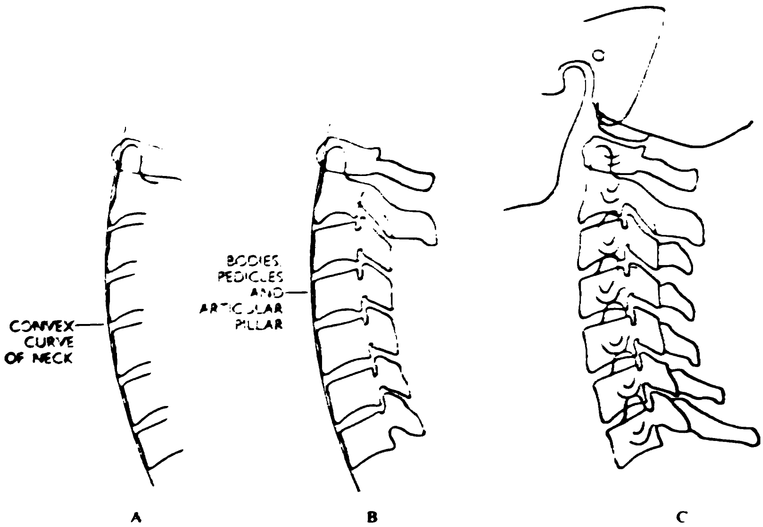


FIG. 142
Cervical vertebrae: a method of constructing the diagram of the lateral radiograph.

Cervical Vertebrae : Oblique Antero-posterior Radiograph (Fig. 143)

Oblique projections of the cervical vertebrae are taken to show the intervertebral foramina, whence the spinal nerves emerge from the vertebral canal. The subject is rotated 45° and the X-ray tube is tilted 15° toward the head in order to project the X rays up into the foramina: the foramina of the side nearest the tube will be clearly demonstrated. If, however, an oblique postero-anterior radiograph is taken, the tube tilt must be in a downward direction, and the foramina of the side nearest the film will then be shown.

Radiography of the Thoracic Vertebrae

It is difficult to take a single radiograph of all twelve thoracic vertebrae owing to the differing radiographic densities of the overlying tissues. In the antero-posterior view considerable regional contrast exists between the transradiant air-filled trachea above and the denser shadows of the heart and subdiaphragmatic viscera below. The superimposed shoulder structures in the lateral position make it difficult to include the upper two vertebrae with the lower ten, and should examination of this area be required oblique radiographs may have to be taken. The superimposed lung tissue may also obscure detail of the vertebrae in the lateral position unless the radiograph is taken with the patient breathing quietly.

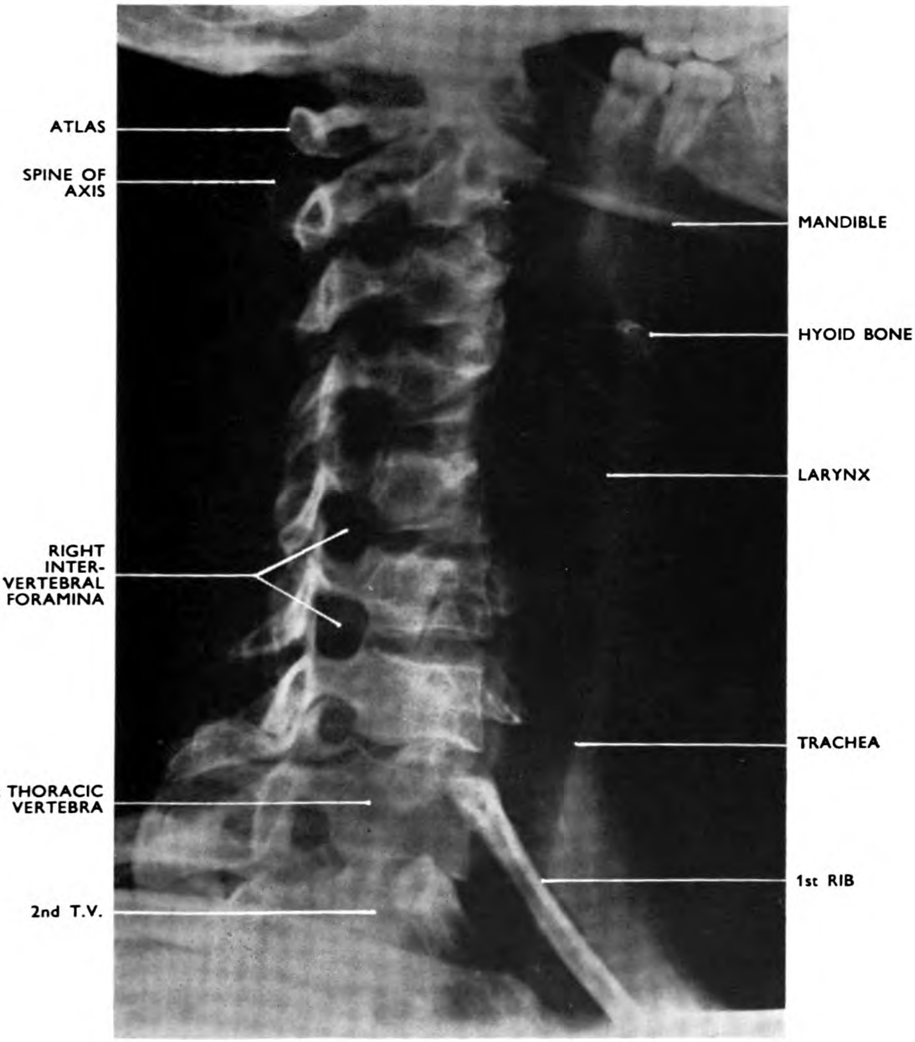


FIG. 143
Cervical vertebrae : oblique antero-posterior radiograph : right foramina shown.

Thoracic Vertebrae : Antero-posterior Radiograph (Fig. 144)

Although long narrow films are usually employed, the illustration given covers the whole thorax to show the anatomical relations more clearly. To assist correct location of a vertebra it is helpful to include the seventh cervical and the first lumbar vertebrae in the radiograph.

The sides of the bodies are slightly concave but the upper and lower surfaces are flat, although the corners are clipped where the demi-facets for the heads of the ribs occur. The shadows of the long, thin, spinous processes can be seen through the centres of the bodies and on either side of the bodies are the

round shadows of pedicles seen end-on, indicating the width of the vertebral canal. The articular processes are almost obscured by the bodies and pedicles. The heads of the first and lower three ribs articulate with full facets on the sides

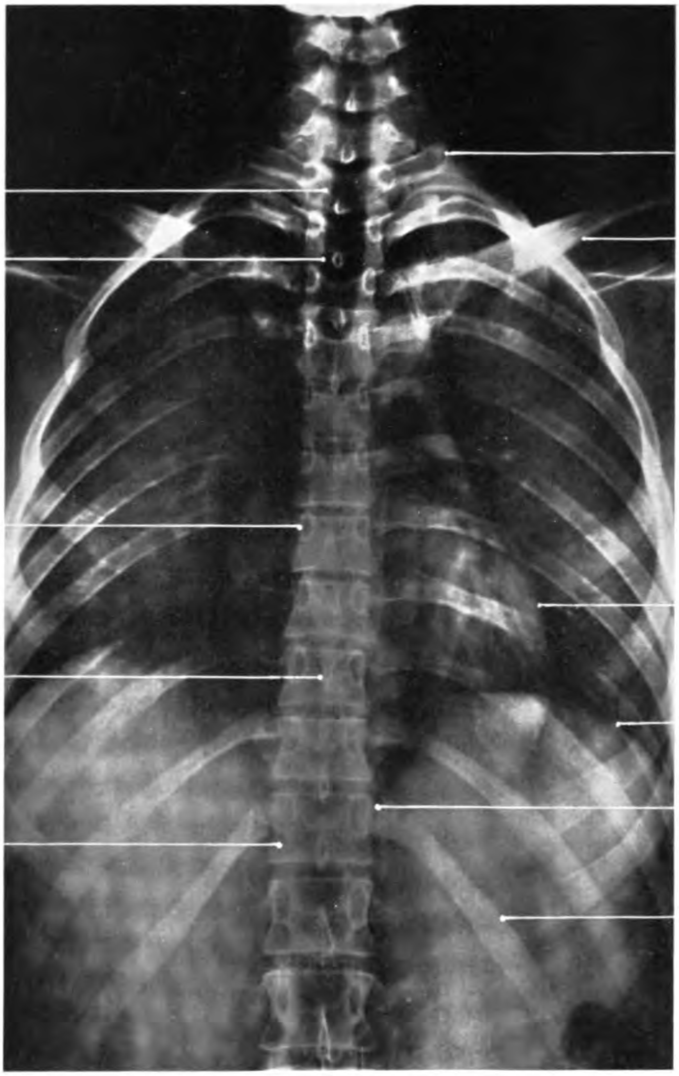


FIG. 144

Thoracic vertebrae : antero-posterior radiograph.

of their respective vertebrae, but the other ribs articulate with the demi-facets on the sides of two adjacent vertebrae. The relationship of the transverse processes to their respective ribs indicates that the upper transverse processes lie behind the ribs, but the lower transverse processes are slightly below the ribs.

The shadow of the air-filled trachea is clearly visible over the bodies of the

upper thoracic vertebrae, and can be traced down to the bifurcation which lies opposite the upper border of the fifth vertebra. The heart and great vessels are indistinctly outlined, but the diaphragm is clearly visible at the level of the ninth to tenth ribs, the right dome being slightly higher than the left. The position of the diaphragm on a radiograph mainly depends on the phase of respiration and the posture of the patient during the exposure.

Thoracic Vertebrae : Lateral Radiograph (Fig. 145)

The anterior concavity of the thoracic spine is clearly demonstrated and this can be seen to be due to the fact that the bodies are slightly deeper behind

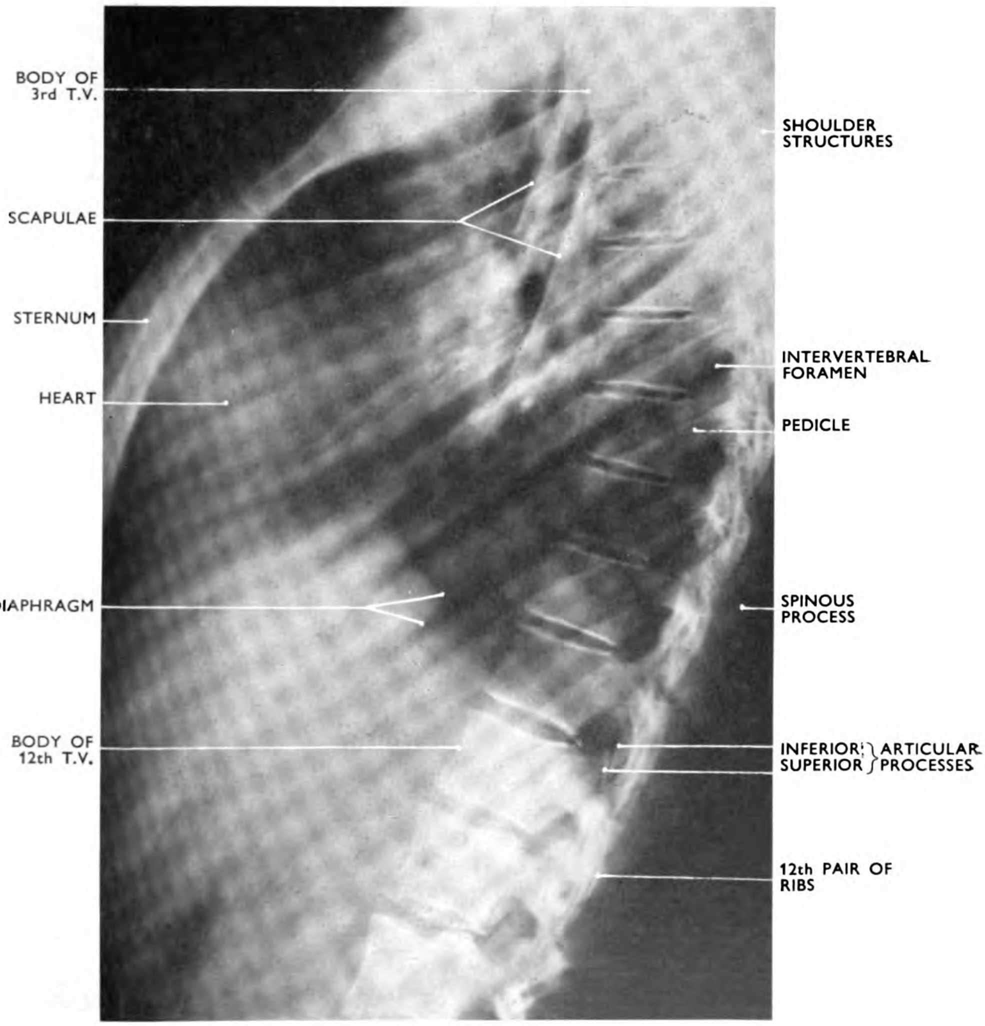


FIG. 145
Thoracic vertebrae : lateral radiograph.

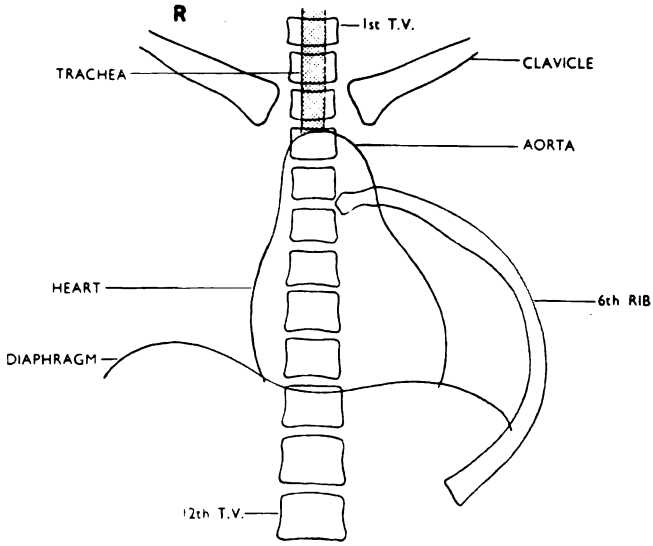


FIG. 146
Thoracic vertebrae: a simplified diagram of the antero-posterior radiograph.

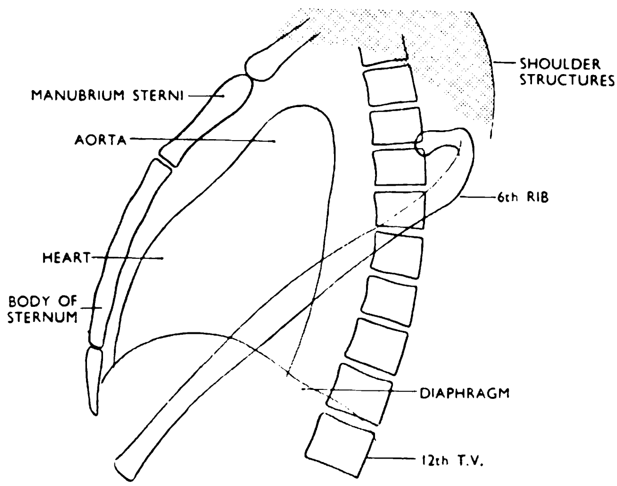


FIG. 147
Thoracic vertebrae: a simplified diagram of the lateral radiograph.

than in front. The upper two vertebrae are completely obscured by the superimposed shadows of the shoulders, but the bodies are seen to increase in size from the third to the twelfth. The intervertebral disc spaces are narrower than in the cervical or lumbar regions, as movement is relatively limited. The pedicles and inferior vertebral notches can be identified, although overshadowed by ribs: the superior vertebral notches are almost absent in the thoracic region.

The inferior vertebral notches form the major part of the intervertebral foramina and face almost laterally. The long spinous processes project very obliquely downward in the mid-thoracic region, but become more horizontal toward the lumbar region.

The articular facets cannot all be clearly seen owing to the overlying rib shadows, but on this particular radiograph the inferior facets of the eleventh and the superior facets of the twelfth vertebrae can be identified: a clear joint space is visible and shows that the plane of the joints is almost vertical.

Simplified diagrams of the antero-posterior and lateral radiographs of the thoracic vertebrae are given in Figures 146 and 147.

Radiography of the Lumbar Vertebrae

In both the antero-posterior and lateral radiographs, the twelfth thoracic vertebrae and the first sacral segments are included to enable identification of a particular lumbar vertebra to be easily made. Unless adequate preparation of the patient is carried out, the gas and faecal contents of the intestines may partly obscure detail of bone structures, particularly in the antero-posterior radiograph. In the lateral radiograph the crests of the iliac bones overshadow the lower part of the body of the fourth and the whole of the fifth vertebra and may cause difficulty, especially where only X-ray apparatus of low power is available.

Lumbar Vertebrae : Antero-posterior Radiograph (Fig. 148)

The body of the twelfth thoracic vertebra can be recognised by its articulation with the twelfth or lowest pair of ribs. The lumbar bodies, with their concave sides and flat upper and lower surfaces, increase in size from the first to the fifth. In the upper lumbar region the circular shadows of the pedicles are clearly seen on either side of the body and demonstrate the increased width of the vertebral canal in this region as compared with the thoracic region. The thick spinous processes, triangular in shape when seen end-on, are visible through the bodies and partly overshadow the relatively wide intervertebral spaces. The inferior and superior articular facets can be identified, the superior pair enclosing the inferior pair of the vertebra above. The plane of the joints, which is almost transverse in the thoracic region, has now turned to become almost sagittal, so that the joint spaces can often be seen. It may assist the student to study the five processes, one spinous and four articular, as a group, for it will be observed that their shadow resembles that of a butterfly in shape, as shown in the outlined illustration (Fig. 149).

The third pair of transverse processes are the longest, whilst the fifth pair are the shortest and stoutest and incline slightly upward. The outer margin of the psoas major muscle, which takes origin mainly from the transverse processes, can often be identified running downward and slightly outward from the sides of the first lumbar vertebra: the muscle shadow is often lost as

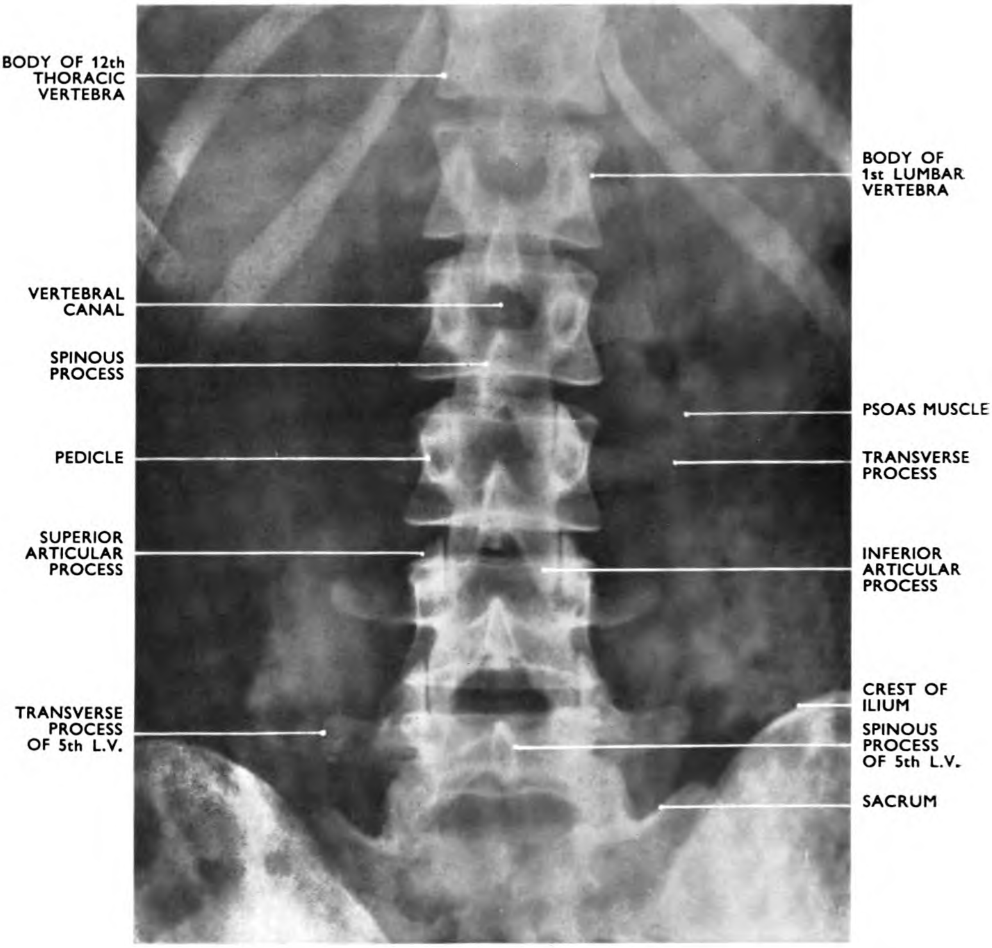


FIG. 148
Lumbar vertebrae: antero-posterior radiograph.

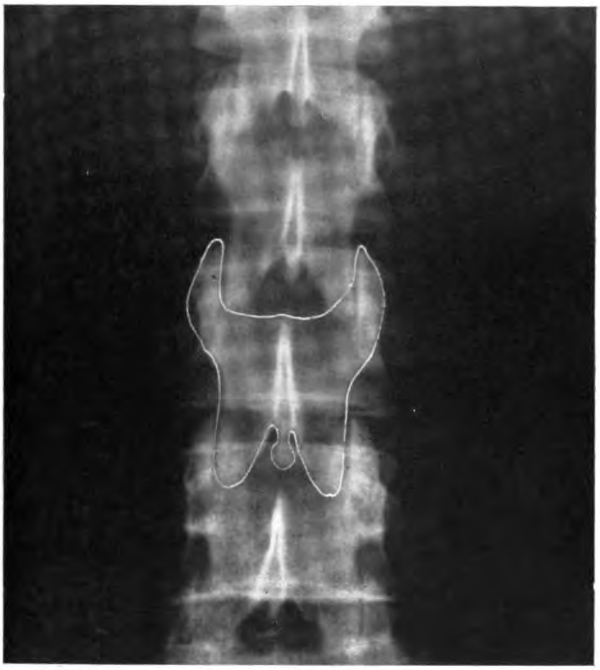


FIG. 149
Lumbar vertebra: spinous and articular processes.

it passes over the iliac crest, but it can sometimes be seen again at its insertion into the lesser trochanter of the femur in radiographs of the pelvis.

The body of the fifth vertebra is the largest of all the vertebral bodies and forms the lumbosacral joint with the first sacral segment: the body is appreciably deeper in front than behind and the lumbosacral joint is therefore inclined at an angle to the X rays and no clear joint space can be seen. The spinous process of this vertebra is smaller in size than the others to allow for the backward curve of the sacrum. Occasionally the transverse processes of the fifth vertebra fuse with the transverse elements of the sacral segment (Fig. 150), a condition known as sacralisation of the fifth lumbar vertebra.

FIG. 150
Showing sacralisation of fifth lumbar vertebra.

Lumbar Vertebrae : Lateral Radiograph (Fig. 151)

The twelfth thoracic vertebra, with its short ribs projecting downward behind the body, will enable the first lumbar vertebra to be identified.

The lumbar curve, convex forward, is mainly due to the intervertebral discs, which are slightly thicker in front than behind, but at the lumbosacral junction the body of the fifth vertebra is appreciably deeper in front than behind. All surfaces of the bodies are slightly concave and the intervertebral spaces much wider than in the thoracic region, as mobility of the lumbar spine is greater. The stout pedicles are seen to be attached high up on the posterior surface of the bodies with large intervertebral foramina below which face directly outward. The plane of the articular facets is very oblique to the X rays on this lateral radiograph, but the facets can be identified although they are superimposed. The short spinous processes project almost horizontally backward but owing to their lighter bony structure they are difficult to see. The shadows of the highest points of the iliac crest overshadow the fifth vertebra, and sometimes part of the fourth. The sacral promontory, which is the prominent anterior upper margin of the body of the first sacral segment, is a well-defined landmark.

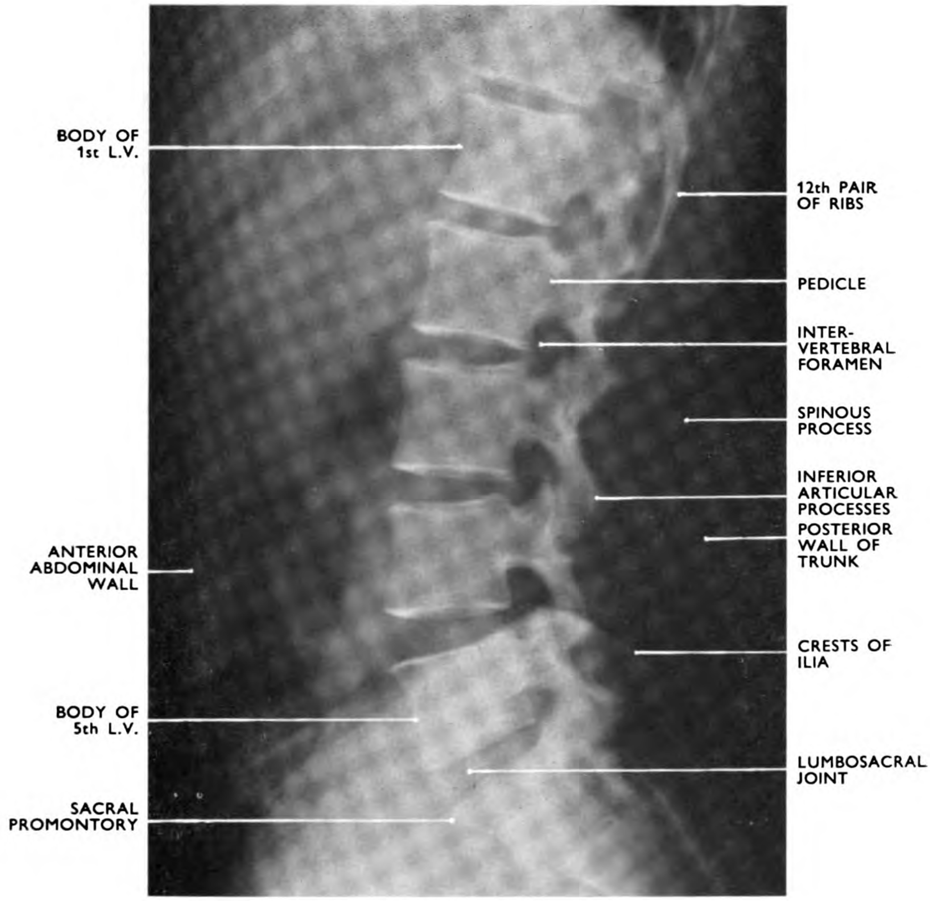


FIG. 151
Lumbar vertebrae: lateral radiograph.

Lumbar Vertebrae : Oblique Radiograph (Fig. 152)

Oblique radiographs of the lumbar vertebrae are taken to demonstrate the articular facets. The bony bridge between the superior and inferior facets is sometimes known as the pars interarticularis and is particularly susceptible to damage: when this occurs one vertebral body may slip forward or backward on another (spondylolisthesis).

In the radiograph the shadows of the processes can be likened in shape to a small dog. On the side under examination, the transverse process represents the snout, the superior articular process the ears, the pedicle the eye, the inferior articular process the forepaws and the pars interarticularis the neck of the animal: its rounded tail and hind legs are supplied by the superior and inferior articular processes of the other side of the vertebra. The interarticular joint spaces are also clearly demonstrated.

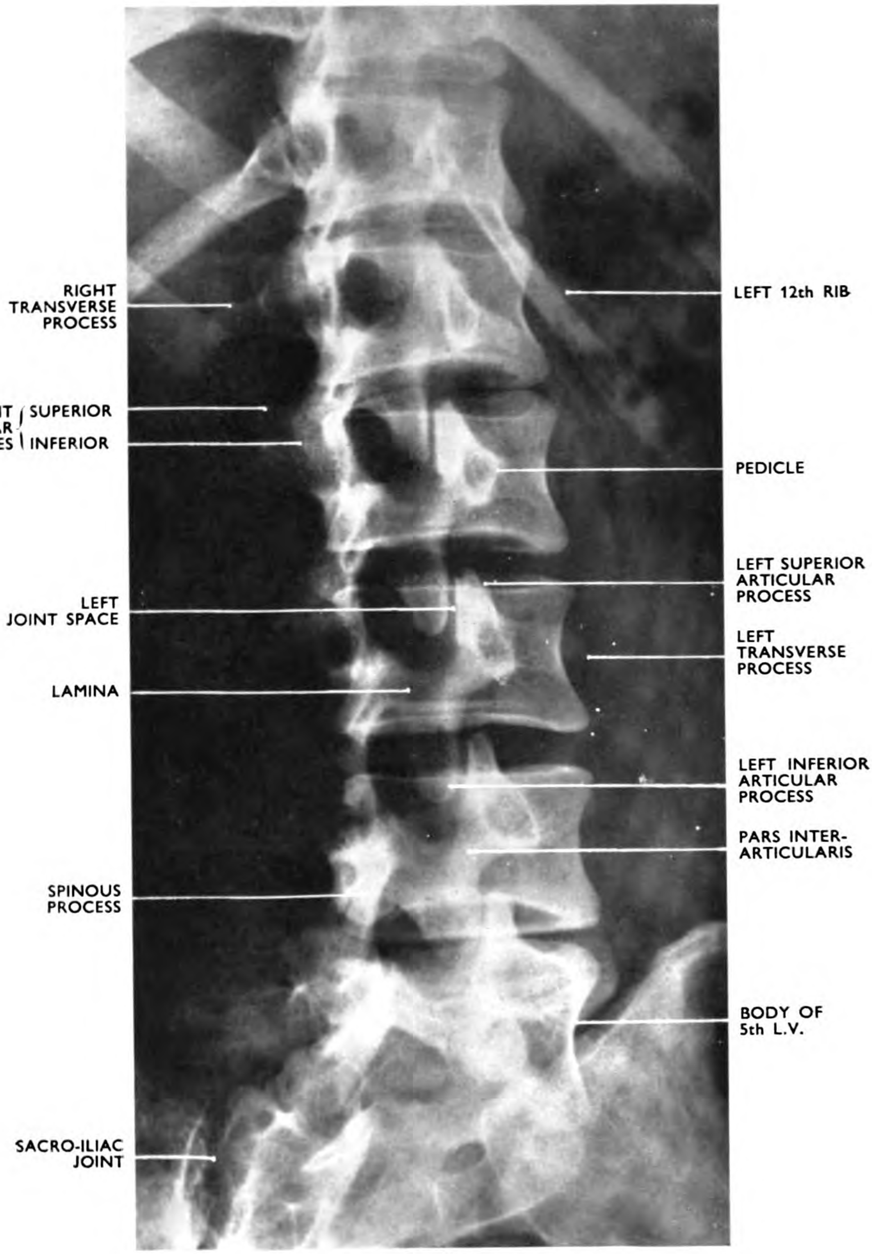


FIG. 152
Lumbar vertebrae: left oblique radiograph.

Radiography of the Sacrum and Coccyx

Preparation of the patient prior to radiography is highly desirable as gas and faecal shadows in the pelvic colon and rectum may make identification of the bony features very difficult, especially in the case of the coccyx.

The curvature of the sacrum varies between the sexes and between persons of the same sex, and superimposition of the shadow of the symphysis pubis must be avoided. These factors will influence the degree of angulation of the X-ray tube toward the head when taking the antero-posterior radiograph. In the lateral radiograph, the marked difference in density between the sacrum and coccyx makes it difficult to produce a radiograph of these two bones on one film, and they may have to be examined separately. The sacral spines can be felt beneath the skin and the tip of the coccyx can be located at the top of the natal cleft.

Sacrum : Antero-posterior Radiograph (Fig. 153)

The central part of the sacrum appears denser than the rest and consists of the bodies of the individual segments: the divisions between the segments cannot usually be identified in the antero-posterior radiograph of an adult. The shadows of the upper two spinous tubercles can be seen in the midline: the lower two tubercles are missing as in this subject the sacral hiatus extends higher than usual to the third segment. On either side of the central area of denser bone of the bodies are the articular tubercles, four on each side, and situated on the posterior surface of the bone. The body of the first segment is wider and more massive than the others, and its superior surface articulates with the fifth lumbar vertebra to form the lumbosacral joint. The superior articular facets of the first segment can be identified and are overshadowed by the inferior facets of the last lumbar vertebra. Immediately outside the line of the articular tubercles the intervertebral foramina are visible. The lateral part of the first segment is large and on its lateral margin can be seen the upper part of the sacro-iliac joint. The lateral parts of the lower sacral segments progressively diminish in size.

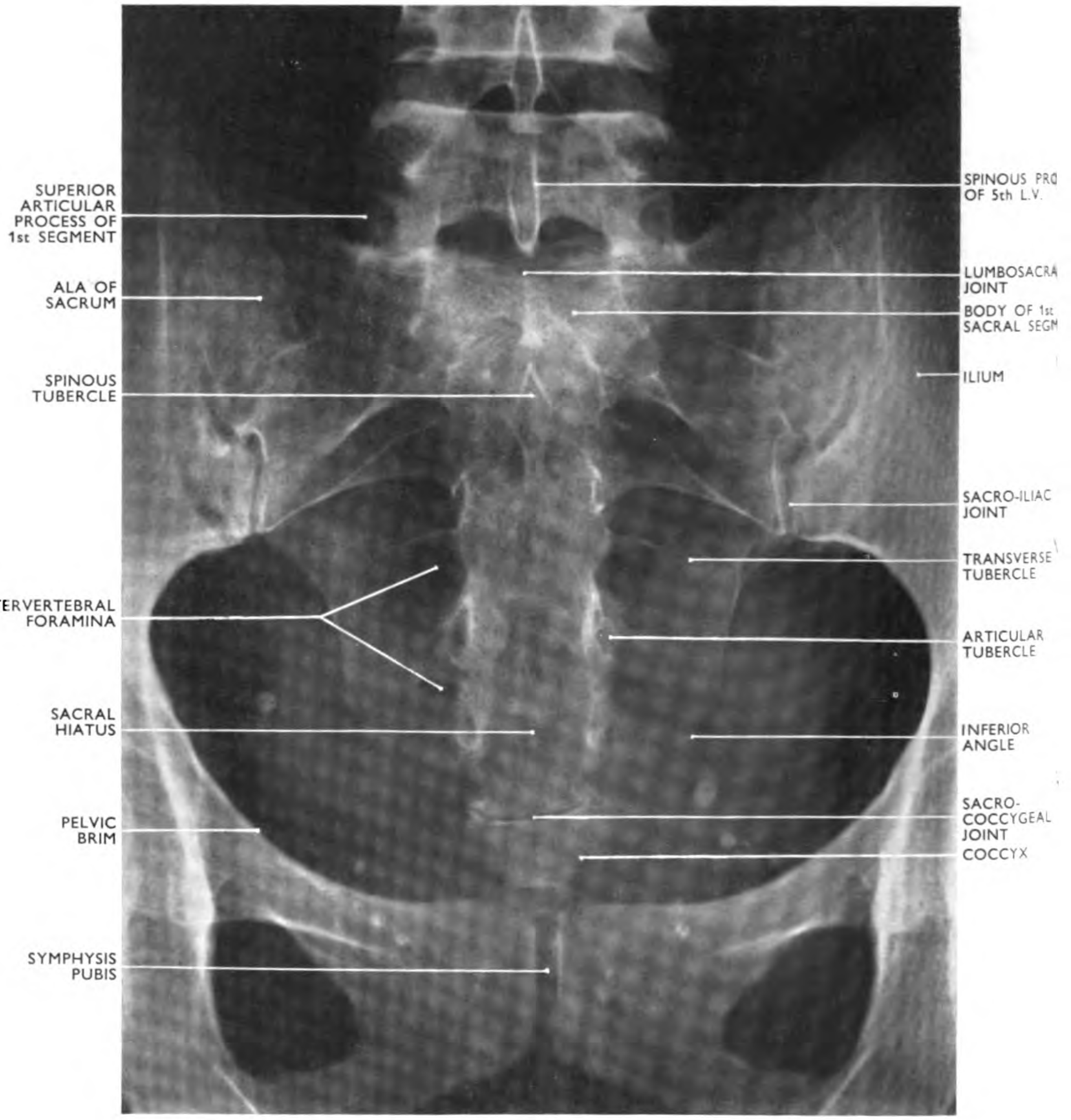


FIG. 153
Sacrum: antero-posterior radiograph.

Sacrum and Coccyx : Lateral Radiograph (Fig. 154)

The lateral radiograph demonstrates the anterior concavity of the sacrum. The individual sacral segments can be identified and are seen to diminish rapidly in size. The upper margin of the first segment forms the sacral promontory, an important landmark in obstetric radiography. A narrow channel,

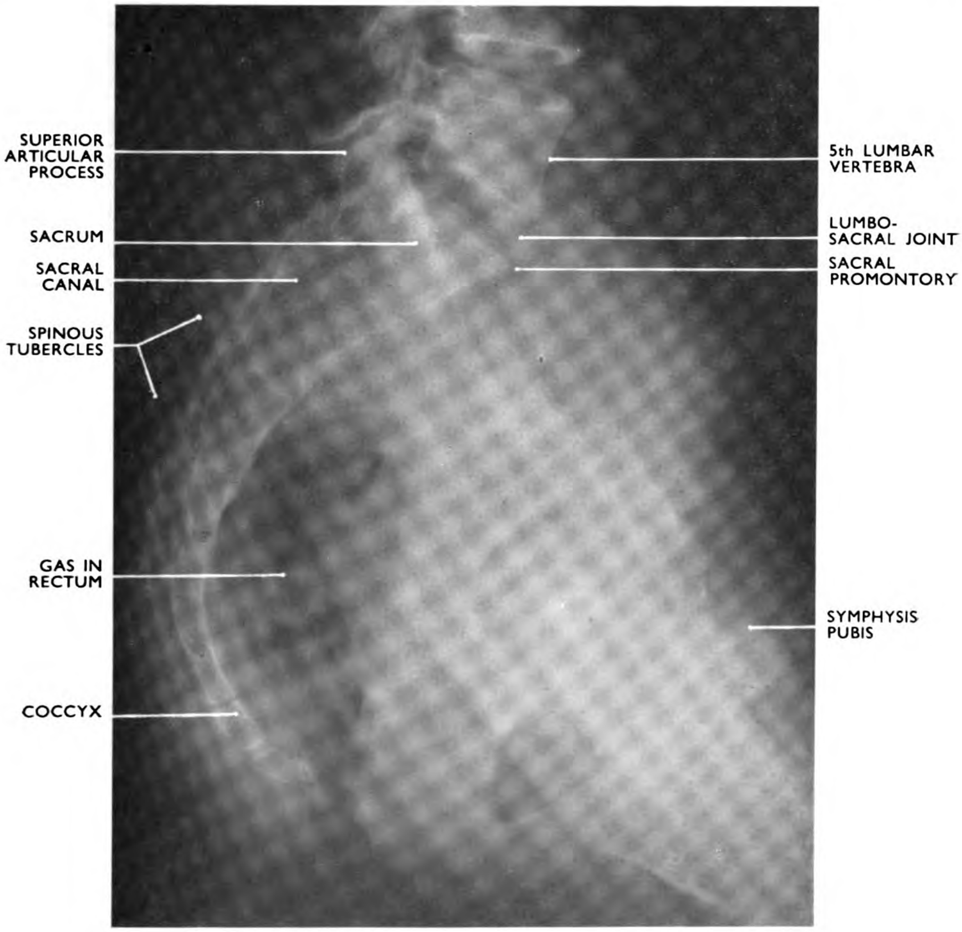


FIG. 154
Sacrum and coccyx: lateral radiograph.

the sacral canal, separates the posterior surfaces of the sacral bodies from the shadow of the fused laminae: this bony roof of the sacral canal can be seen to end above the tip of the fifth segment and forms the upper margin of the sacral hiatus.

The coccyx in this subject is formed of two unfused segments and articulates with the apex of the sacrum and continues the general concavity of the anterior sacral surface.

Coccyx : Antero-posterior Radiograph (Fig. 155)

It is usually necessary, particularly in male subjects, to tilt the X-ray tube toward the feet so as to prevent superimposition of the symphysis pubis.

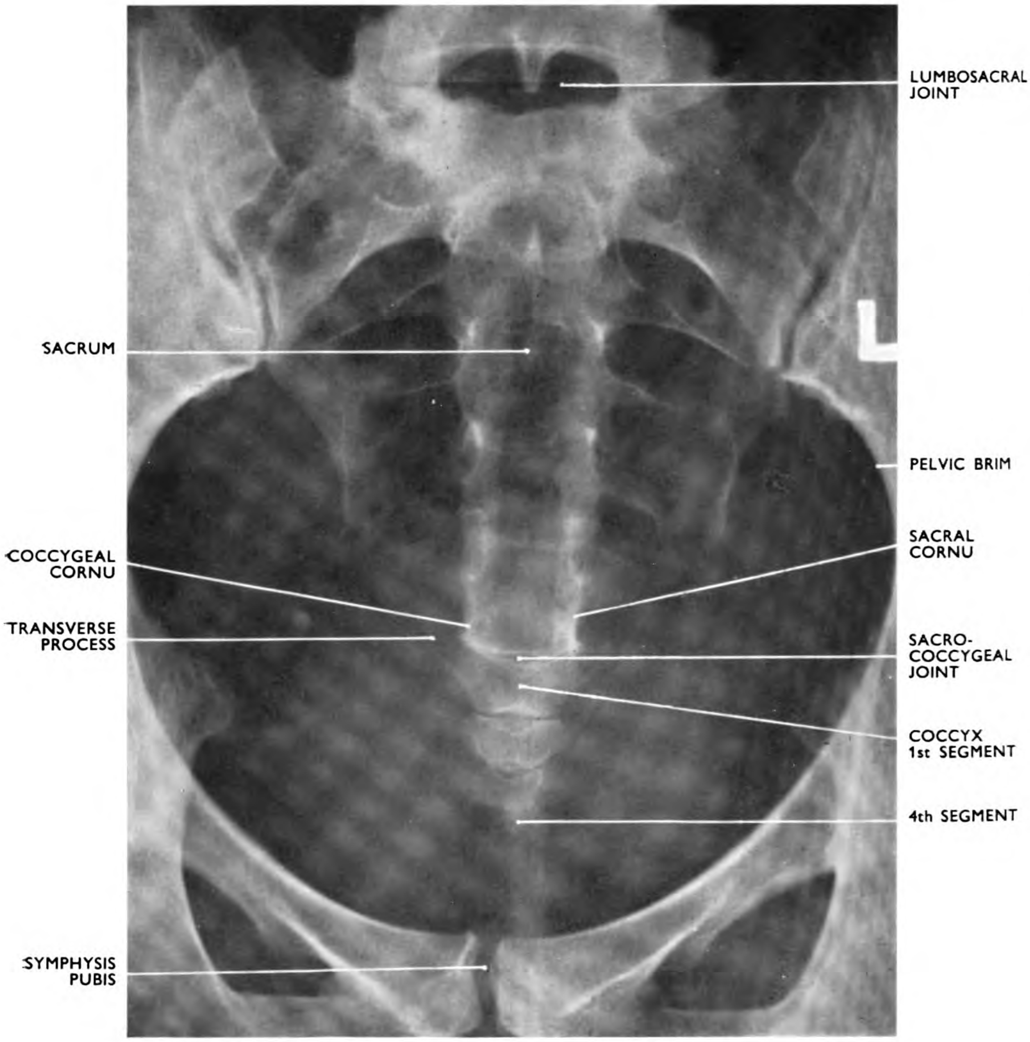


FIG. 155
Coccyx: antero-posterior radiograph.

Four coccygeal segments are visible, rapidly diminishing in size. The rudimentary transverse processes of the first segment are well shown, but the cornua, which correspond to the superior articular facets of a typical vertebra, are overshadowed by the sacral cornua.

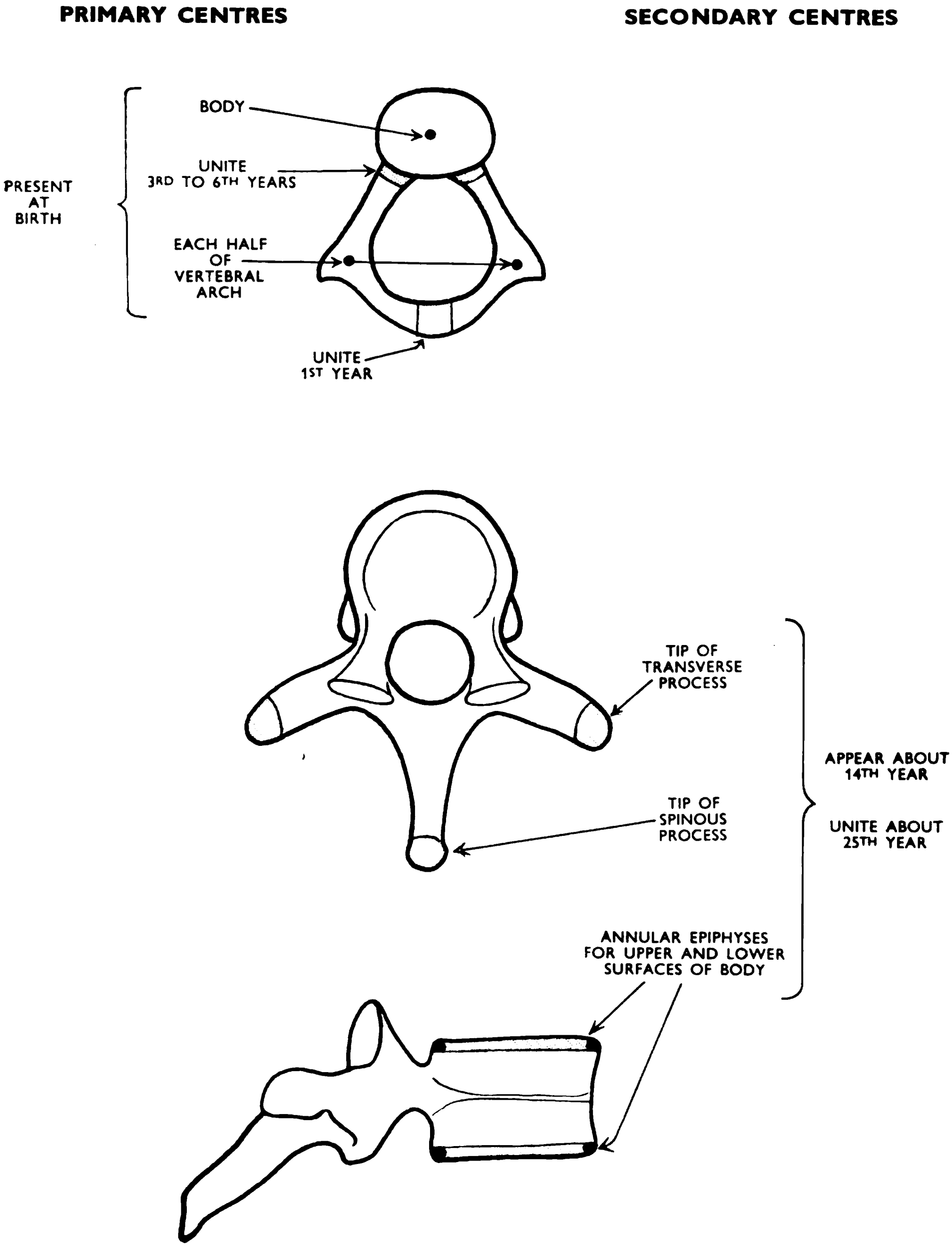
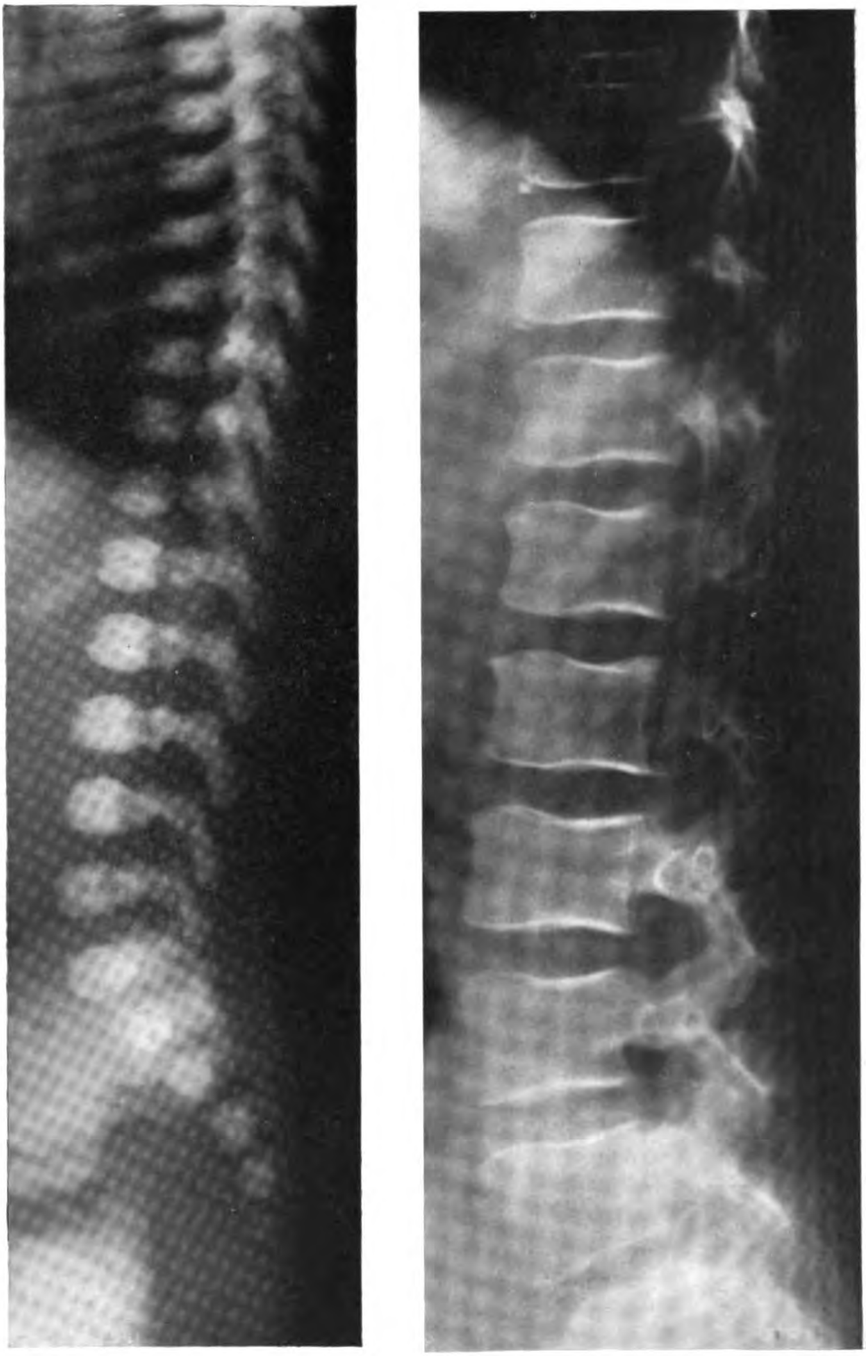


FIG. 156
Ossification of a typical vertebra.

Ossification of the Vertebral Column (Fig. 156)

A typical vertebra ossifies from **three primary centres,** one for the body and one for each half of the vertebral arch ; these centres appear in early intrauterine life and at birth are the only centres visible on a radiograph.



A B

FIG. 157

In infancy (Fig. 157, A) the vertebral bodies appear bobbin-shaped on a lateral radiograph, with deep notches in the middle of the anterior and posterior surfaces; these notches are due to large venous channels, which may sometimes be traced completely through the body. The notches and channels gradually become less marked with time, but may sometimes be faintly seen up to puberty.

The two halves of the arch unite during the first year, commencing in the lumbar region and extending upward; fusion of the bodies and the complete arches takes place between the third and sixth year.

Shortly after puberty **five secondary centres** appear, one for the tip of the spinous process, one for the tip of each transverse process and two annular epiphyses for the upper and lower surfaces of the vertebral bodies. Prior to the appearance of the annular epiphyses, a lateral radiograph (Fig. 157, B) will show a small step in the upper and lower margins of the anterior surface of the bodies: a small triangular centre of ossification develops in this step and forms a complete ring round the upper and lower surfaces of the bodies. All secondary centres unite with the rest of the bone about the twenty-fifth year.

The chief exceptions to this method of ossification occur in the first, second and seventh cervical vertebrae, and in the sacrum and coccyx.

1. The **atlas** ossifies from three primary centres, one for the anterior arch and one for each lateral mass. The centres for the lateral masses appear in intrauterine life, but the centre for the anterior arch does not appear until the first year.

2. The **axis** has two additional primary centres, one for each side of the odontoid process, making five in all.

3. The **seventh cervical vertebra** has two additional centres for the anterior part (costal element) of the transverse processes: these centres normally fuse with the rest of the bone about the fifth year, but they may remain separate and grow to form cervical ribs.

4. The **sacrum** has the usual primary centres, but there are a number of additional secondary centres, including one for each auricular surface.

5. In the **coccyx** each segment ossifies from one primary centre.

The vertebral column becomes fully ossified about the twenty-fifth year.

Developmental abnormalities of the vertebral column are not uncommon, and often tend to be multiple: the two commonest are cervical ribs and spina bifida. Spina bifida is due to failure of fusion of the laminae of the vertebral arch and usually occurs in the lower lumbar or sacral regions. The secondary centres for the transverse processes may persist as separate ossicles and be mistaken for fractures. Sacralisation of the fifth lumbar vertebra has already been mentioned. Severe defects, such as partial failure of development of the bodies of the vertebrae, are rare and when they occur scoliosis or lateral curvature of the spine is usually present.

CHAPTER VI

THE BONES OF THE THORAX

THE skeleton of the thorax is formed by the twelve thoracic vertebrae, twelve pairs of ribs and costal cartilages and the sternum. All the ribs articulate behind with the vertebral column, but only the upper seven are connected to the sternum in front by costal cartilages. This elastic framework

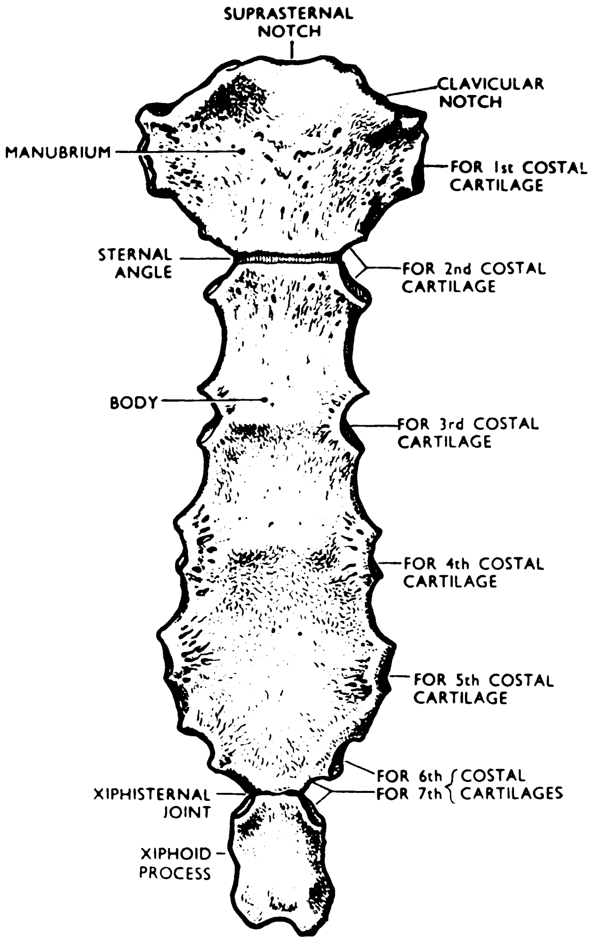


FIG. 158
Sternum: anterior aspect.

protects the heart, great vessels and lungs; it also gives attachment to the upper limbs and some of the muscles of the shoulder region. The diaphragm which separates the thoracic from the abdominal cavity is partly attached to the ribs, as are many of the muscles of the abdominal wall and back.

Sternum (Figs. 158 and 159)

This long flat bone lies in the midline in the front of the thorax, and is directed downward and slightly forward. Its upper end supports the clavicles at the sterno-clavicular joints, and laterally it gives attachment to the costal cartilages of the upper seven pairs of ribs.

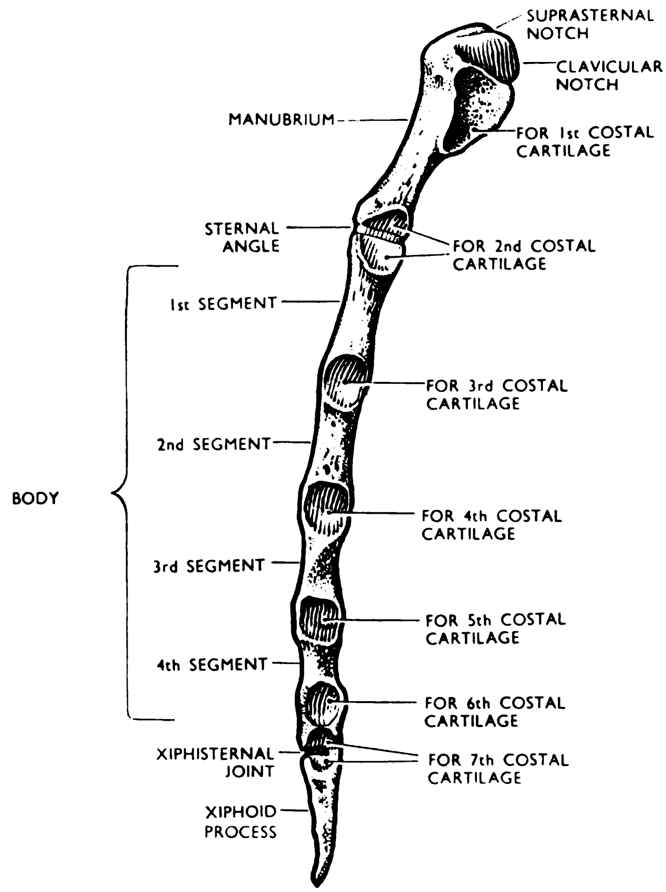


FIG. 159
Sternum: lateral aspect.

The sternum consists of three parts—the manubrium, the body and the xiphoid process.

The **manubrium sterni** is roughly triangular in shape. The superior border is thick, and on each side of the central suprasternal notch are articular facets (clavicular notches) for the medial ends of the clavicles. A notch is present at the upper end of each lateral border for articulation with the costal cartilage of the first rib; a half notch at the lower end, with a similar half notch on the opposing body of the sternum, receives the costal cartilage of the second rib. The inferior border is narrow and articulates with the upper end of the body

of the sternum to form the sternal angle, a prominent transverse ridge which can be seen and felt through the skin.

The **body** of the sternum is long and narrow. The anterior surface is marked by three ridges which show that the bone is formed by the fusion of four segments. The posterior surface is slightly concave from above down. Each lateral border is marked by four complete notches for articulation with the third to sixth costal cartilages; at its upper and lower ends are half notches, shared with the manubrium and xiphoid process, and with which the second and seventh costal cartilages articulate.

The **xiphoid process** is the smallest part of the sternum; it articulates with the lower border of the body of the sternum. It is rarely fully ossified in the adult and is variable in shape; sometimes it is perforated or bifid or may be bent to one side. Its superior angle completes the notch for the seventh costal cartilage.

The sternum can be felt through the skin and provides important surface markings. The suprasternal notch lies in the same horizontal plane as the intervertebral disc between the second and third thoracic vertebrae; the sternal angle lies at the level of the disc between the fourth and fifth thoracic vertebrae and the xiphisternal joint is at the level of the disc between the ninth and tenth thoracic vertebrae. The aortic arch reaches its highest point at the level of the centre of the manubrium.

Ribs (Figs. 160 and 161)

There are normally twelve pairs of ribs, but additional cervical or lumbar ribs are sometimes present; occasionally the twelfth pair of ribs are absent. These long slender bones articulate posteriorly with the thoracic vertebrae, and end anteriorly in extensions called costal cartilages. The seven upper pairs of ribs are known as true ribs, since their costal cartilages articulate with the sternum; the lower five pairs (eighth to twelfth) are called false ribs, as they are not directly connected to the sternum. The costal cartilages of the upper three pairs of false ribs (eighth to tenth) are each joined to the costal cartilage directly above, whilst the eleventh and twelfth pairs are unattached, and are known as floating ribs. The ribs progressively increase in length from the first to the seventh and thereafter become shorter. They are inclined downward and forward, so that the anterior end is lower than the posterior end, and are separated from each other by intercostal spaces, occupied in life by intercostal muscles, nerves and vessels.

The first two and the last three pairs of ribs are slightly different from the others, and will be separately described.

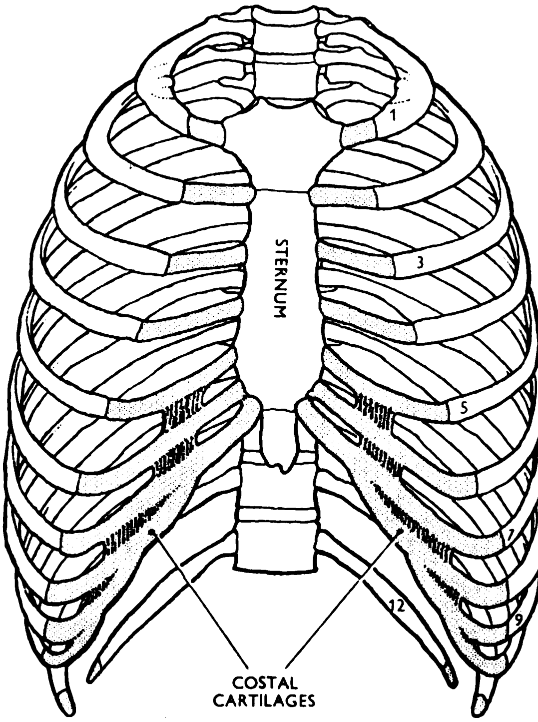


FIG. 160
The bones of the thorax: anterior aspect.

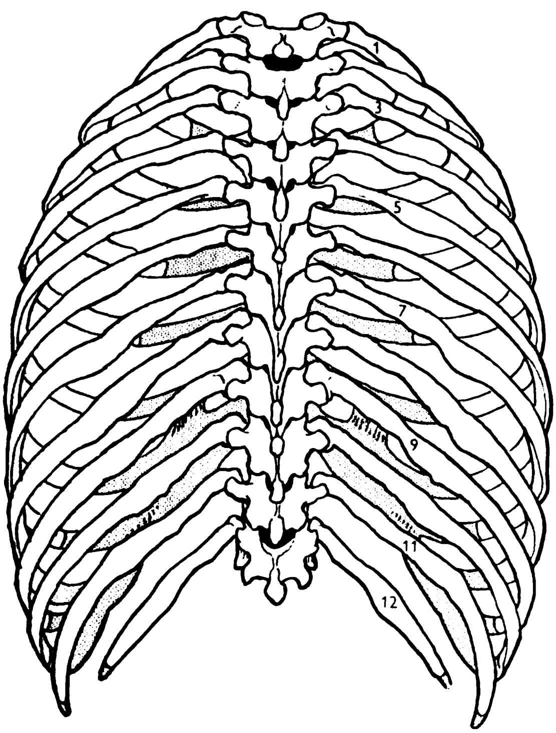


FIG. 161
The bones of the thorax: posterior aspect.

A **typical rib** (Fig. 162) consists of a long curved shaft with anterior and posterior ends.

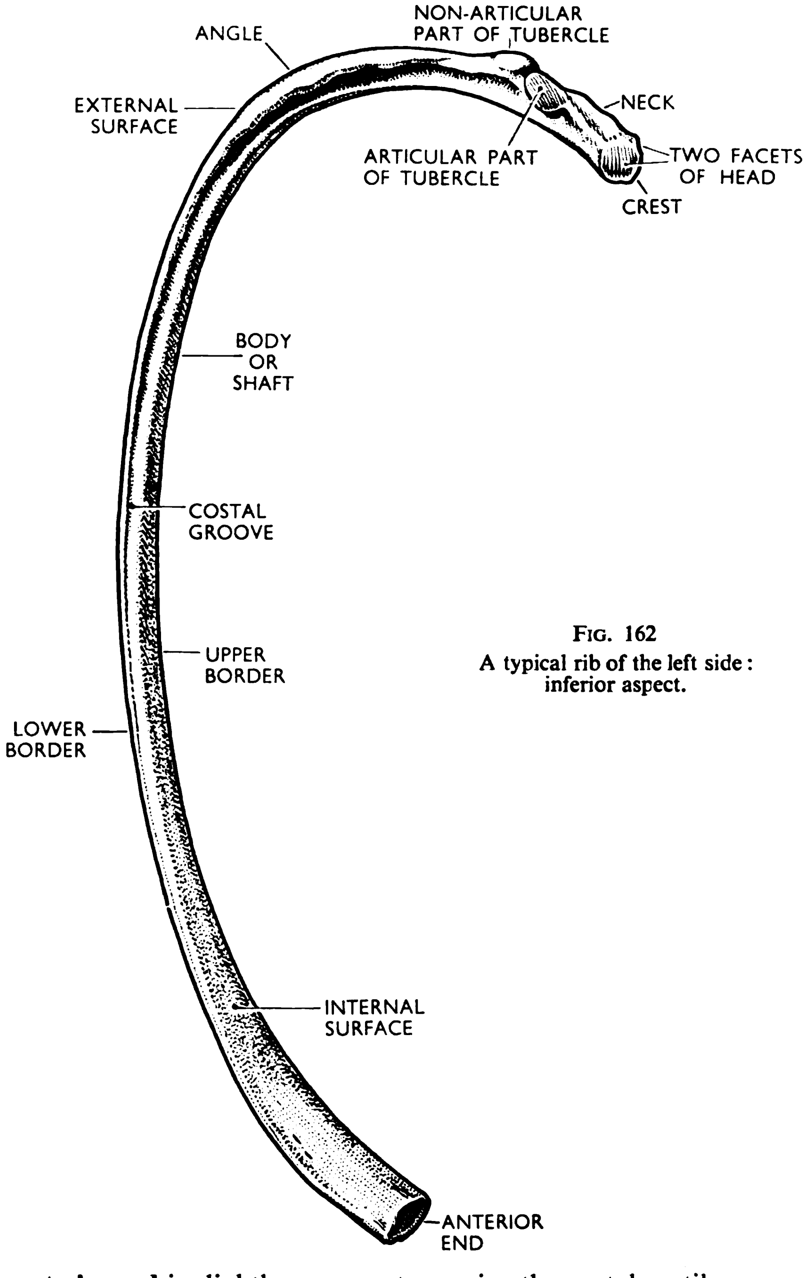


FIG. 162
A typical rib of the left side: inferior aspect.

The **anterior end** is slightly concave to receive the costal cartilage.

The **posterior end** consists of a head, neck and a tubercle.

The **head** is covered with articular cartilage and is divided by a transverse crest into upper and lower facets; these articulate with demi-facets on two

adjacent vertebrae to form the costo-vertebral joint. The crest is attached by a ligament to the intervertebral disc. (The rib takes the number of the lower vertebra.)

The **neck** is the short flattened portion of the rib between the head and the tubercle. It lies in front and slightly above the transverse process of the corresponding vertebra to which it is attached by ligaments.

The **tubercle** is a bony protuberance on the posterior surface of the rib,

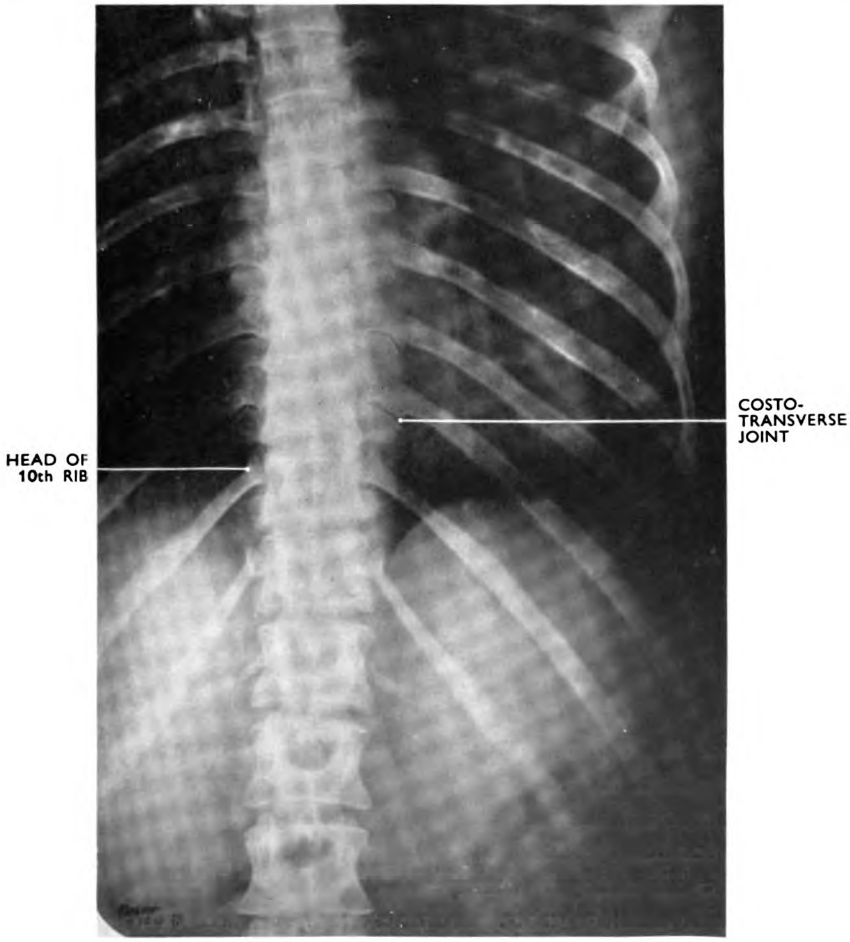


FIG. 163

Ribs: antero-posterior radiograph showing costo-transverse joints.

at the junction of the neck and shaft. It is divided into a lateral non-articular part and a medial articular facet, which articulates with the facet on the transverse process of the corresponding vertebra to form the costo-transverse joint (Fig. 163).

The **shaft** is long and flattened from side to side, so that it has an external and an internal surface. The superior border is rounded, and on the inner side of the inferior border is the costal groove, along which the intercostal vessels and nerves pass.

In the articulated skeleton the posterior end of the rib runs obliquely downward and backward as far as the **angle,** where the direction of the shaft changes to that of a gentle forward and inward curve. The shaft also twists slightly, so that toward the anterior end the inner surface faces slightly downward.

The **first rib** (Fig. 164) is short, flat and broad. In contrast with a typical

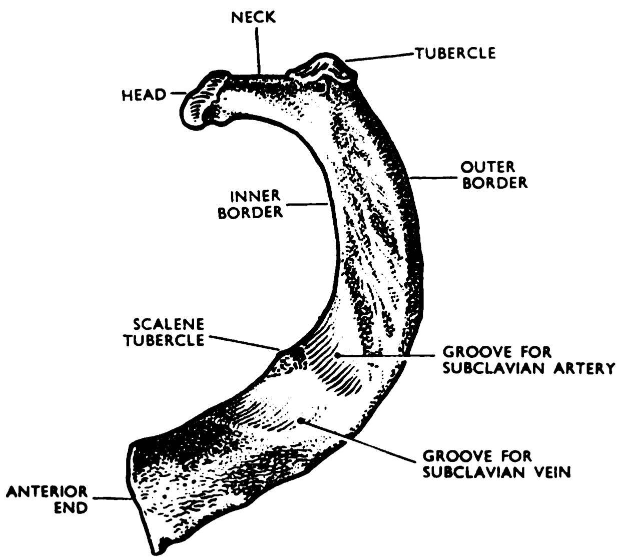


FIG. 164
First rib of left side: superior aspect.

rib, it has upper and lower surfaces and an outer and an inner border. In the articulated skeleton it is directed very obliquely downward and forward. The head bears a single articular facet, since it articulates only with the body of the first thoracic vertebra. The tubercle is prominent, and at this point the direction of the rib changes sharply, so that the tubercle coincides with the angle. Two wide shallow grooves run across the middle of the upper surface and are separated by a small projection on the inner border, the scalene tubercle; the posterior groove is for the subclavian artery, and the anterior groove for the subclavian vein. The first rib has no costal groove and its costal cartilage passes under the clavicle to articulate with the manubrium sterni.

The **second rib** (Fig. 165) is almost twice as long as the first. Its surfaces are in direction intermediate between that of the first rib and that of a typical rib; the external surface faces upward and outward and the internal surface downward and also inward. This rib is not twisted, so that it will rest evenly

on a flat surface. Near the middle of its outer surface there is a well-marked roughness for the attachment of part of the serratus anterior muscle.

The **tenth, eleventh and twelfth ribs** have a single facet on their head. The eleventh and twelfth ribs do not possess a tubercle or a neck, as they do not articulate with the transverse process of the corresponding vertebra.

The **costal cartilages** are flattened bars of hyaline cartilage, joined to the

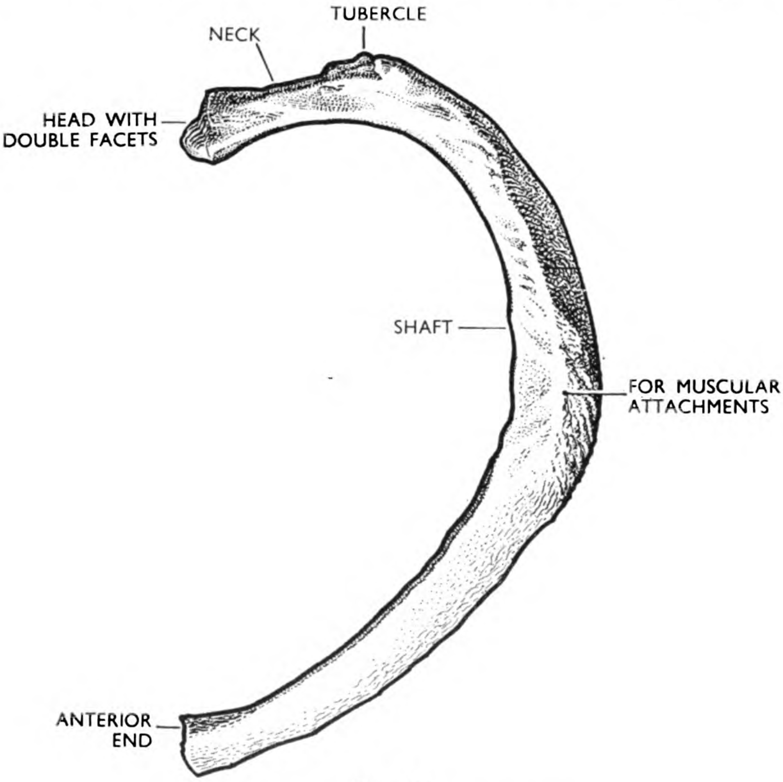


FIG. 165
Second rib of left side: superior aspect.

anterior end of the ribs. The upper seven pairs of cartilages connect the anterior ends of their respective ribs to the sternum; the medial ends of the eighth, ninth and tenth cartilages articulate only with the lower border of the cartilage above and form the lower costal margins between which lies the infrasternal (subcostal) angle.

The Thorax

The skeleton of the thorax is roughly conical in shape. It is bounded posteriorly by the thoracic vertebrae, anteriorly by the sternum and costal cartilages, and laterally by the ribs. It is narrower above than below, and the transverse diameter is greater than the antero-posterior diameter. On

cross-section it is kidney shaped, due to the inward projection of the vertebral bodies and the slight backward curve of the posterior ends of the ribs; the lungs therefore extend behind the plane of the vertebral bodies, and superimposition of their shadows on those of the bodies will be seen on a lateral radiograph of the thorax.

The thoracic inlet is formed posteriorly by the first thoracic vertebra,

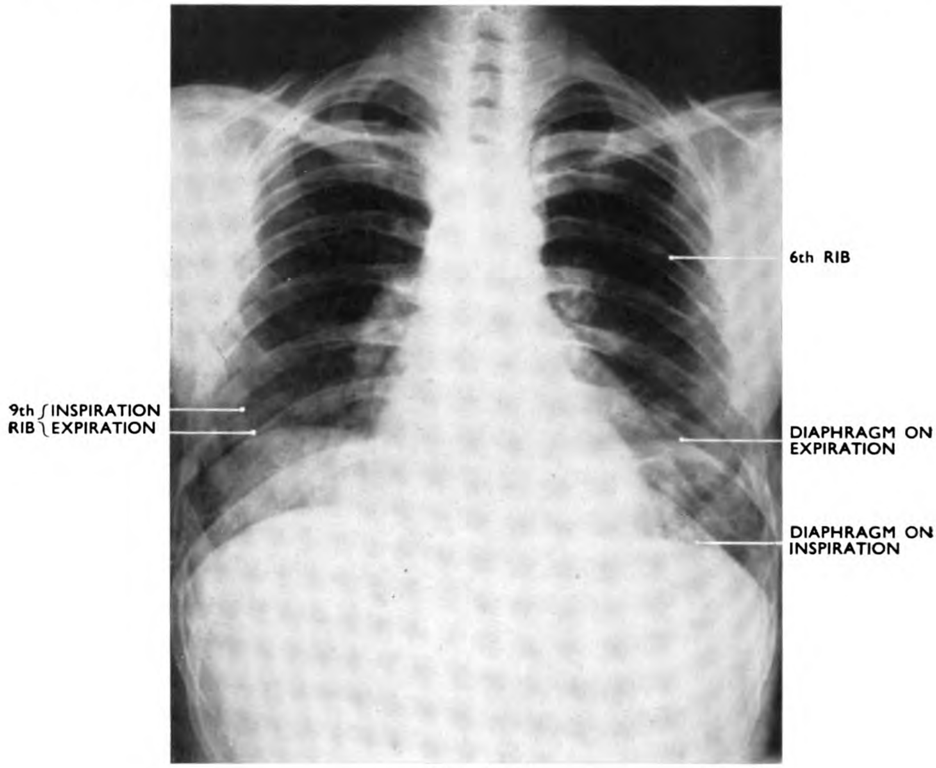


FIG. 166
The diaphragm: showing two exposures on one film to demonstrate its excursion during respiration.

laterally by the first ribs, and anteriorly by the manubrium sterni. It is relatively small and kidney shaped, and is inclined downward and forward. Through this important opening pass the trachea, the oesophagus, the main vessels to the head and upper limbs, and many nerves, including the sympathetic trunk, the vagus and phrenic nerves. The apices of the pleural sacs and lungs project a short distance above the inlet.

The thoracic outlet is considerably larger than the inlet; it is formed by the twelfth thoracic vertebra behind and by the lower margins of the ribs and costal cartilages at the sides and in front. In the living subject the outlet is closed by the diaphragm, which separates the thoracic from the peritoneal cavity. The diaphragm consists of muscle fibres which arise from the upper

lumbar vertebrae, the lower ribs and xiphoid process, and are inserted into a central tendon: the muscle origins are therefore roughly at the level of the thoracic outlet, but the central tendon is situated at a higher level so that the diaphragm is dome-shaped when seen from below. On inspiration, the contraction of the muscle fibres causes descent of the central tendon, and the diaphragm as a whole tends to become flatter. The height of the diaphragm as seen on a radiograph varies with the phase of respiration, the body build of the subject, and the posture. The right dome of the diaphragm normally remains a little higher than the left. During respiration the full range of diaphragmatic movement is about one-and-a-half to two inches (Fig. 166): this change of position is of great significance in radiography, as by control of respiration the diaphragm can be moved into the most suitable position for any given radiographic purpose.

RADIOGRAPHIC APPEARANCES OF THE THORAX

Radiography of the Sternum

For a postero-anterior radiograph of the sternum the trunk must be rotated or the tube tilted, in order to separate the shadow of the sternum from that of the vertebral column. The lung shadows can also confuse the image, and it is usual to make the exposure during quiet breathing to eliminate this effect by movement.

Sternum : Postero-anterior Radiograph (Fig. 167)

For this radiograph the patient is positioned with the sternum in contact with the film, and the tube is tilted slightly inward from the side of the trunk, so as to project the shadow of the vertebral column clear of the sternum: it is usual to make the exposure during quiet breathing, to eliminate the superimposed lung shadows by movement.

The three constituent parts of the sternum are demonstrated. The suprasternal notch in the middle of the superior border of the manubrium is flanked on either side by the slightly inclined clavicular notches: in this radiograph the left sterno-clavicular joint is partly obscured by the shadows of the thoracic vertebrae. The first costal cartilage does not cast a shadow, but joins the manubrium at the slight depression on the upper margin of the lateral border. The joint between the manubrium and body is well shown; the second costal cartilage articulates with both bones at this level, so that each has a half notch on its lateral border. The four complete notches on each side of the body of the sternum, which receive the third to sixth costal cartilages, are visible: the seventh costal cartilage is attached to the half notches on the adjacent borders of the body and xiphoid process. The shadows of the posterior ends of the right upper ribs are superimposed on the sternum, but they do not obscure its main bony features.

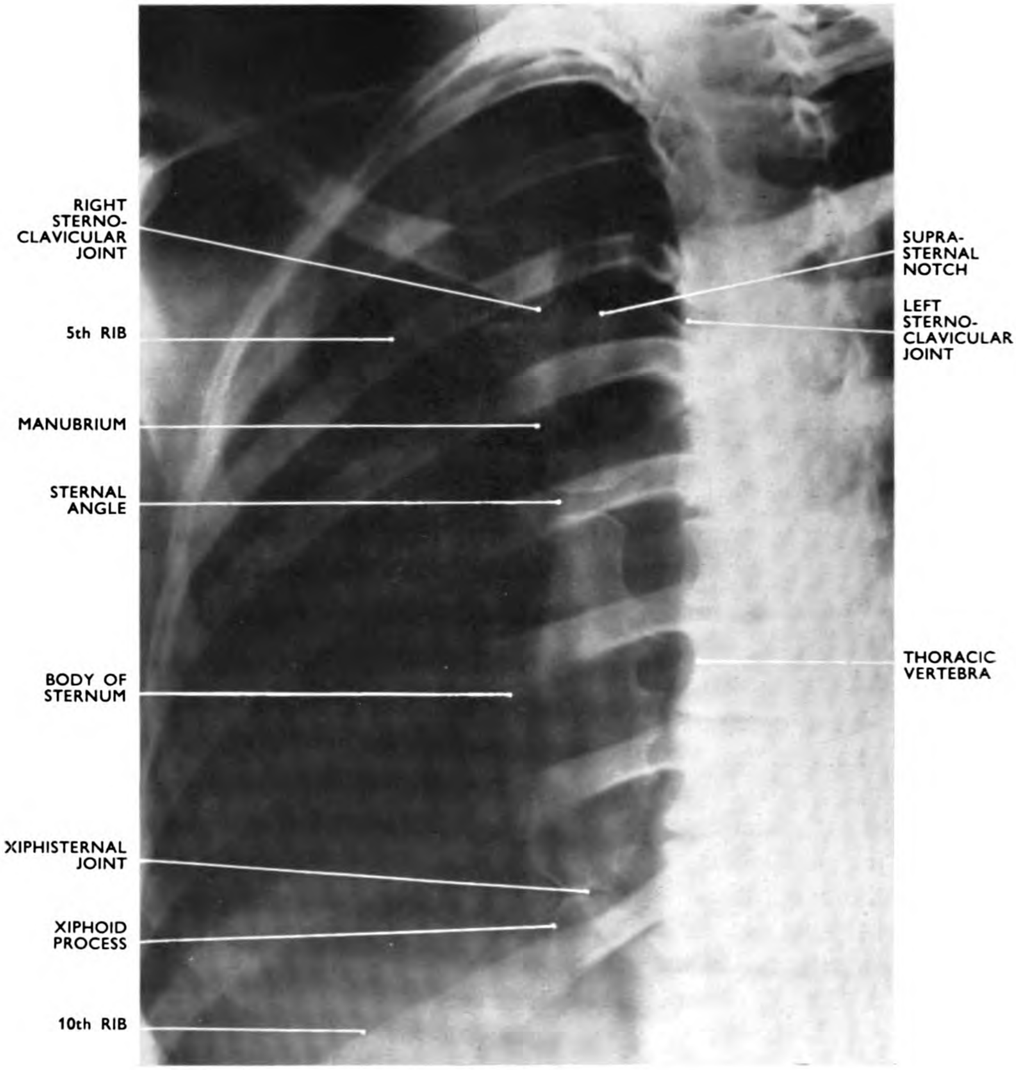


FIG. 167
Sternum: postero-anterior radiograph: tube tilted.

Sternum : Lateral Radiograph (Fig. 168)

A profile view of the sternum is obtained when the trunk is in a lateral position relative to the film. In the adult its shadow may be indistinct due to its distance from the film and to superimposed calcified costal cartilages; the example given here is that of a child, where definition is better, owing to

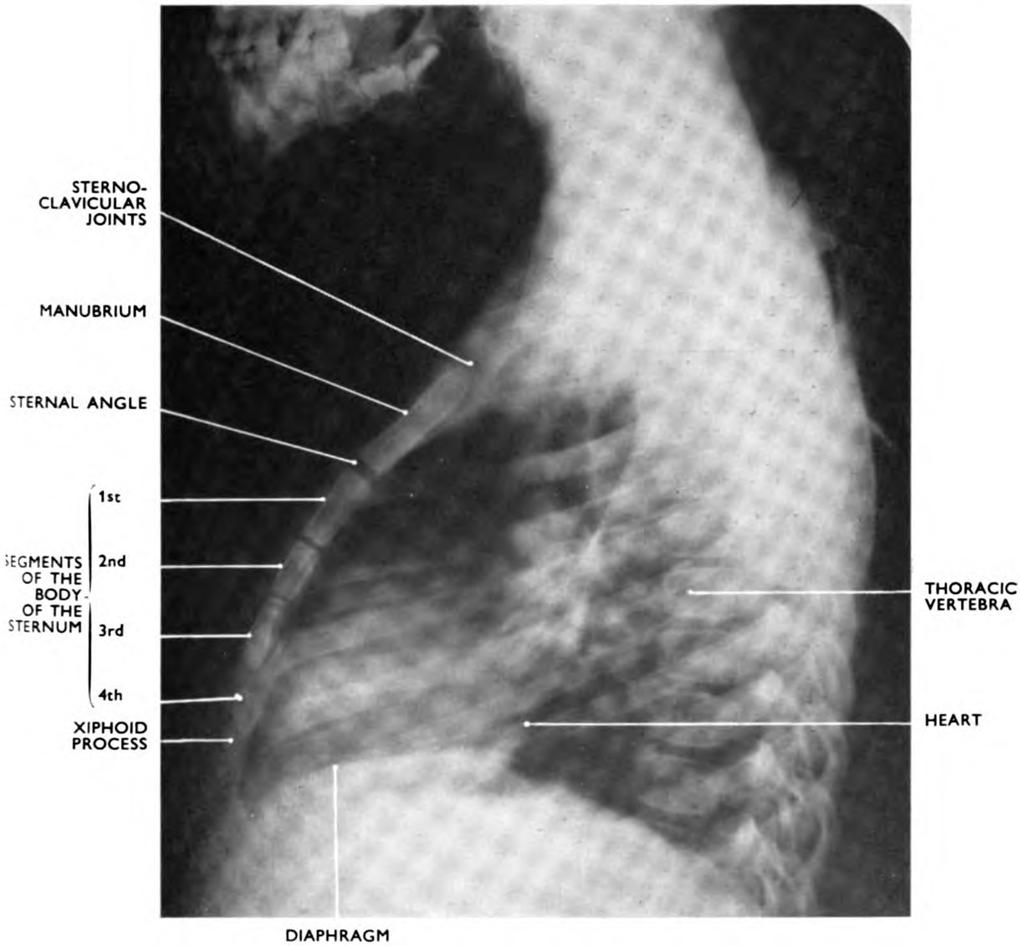


FIG. 168
Sternum : lateral radiograph of a child.

shorter subject-film distance, and where the individual segments which form the sternum can be seen.

The superimposed clavicles can be seen above the superior border of the manubrium ; the secondary centres for the sternal ends of the clavicles have not yet appeared, and the space at the sterno-clavicular joint therefore appears wide. The manubrium is flat, but the sternal angle which it makes with the slightly concave body of the sternum is not marked at this early age.

The four individual segments which form the body are visible: the wide gap between the third and fourth segments is due to incomplete ossification of the last segment. The xiphoid process is only very faintly visible, as ossification has just started.

RADIOGRAPHY OF THE RIBS

All ribs cannot be examined on a single radiograph, as the difference in regional contrast between the areas above and below the diaphragm is too great.

For the upper nine pairs of ribs the exposure is made on inspiration, to bring the diaphragm to its lowest level: the lower ribs are radiographed on expiration, so as to use the subdiaphragmatic area as a uniform background density. Radiographs may be taken with the trunk in an antero-posterior, postero-anterior or oblique position, but in all cases the parts of the ribs nearest the film will be most clearly defined, and this determines the position to be used in any particular case.

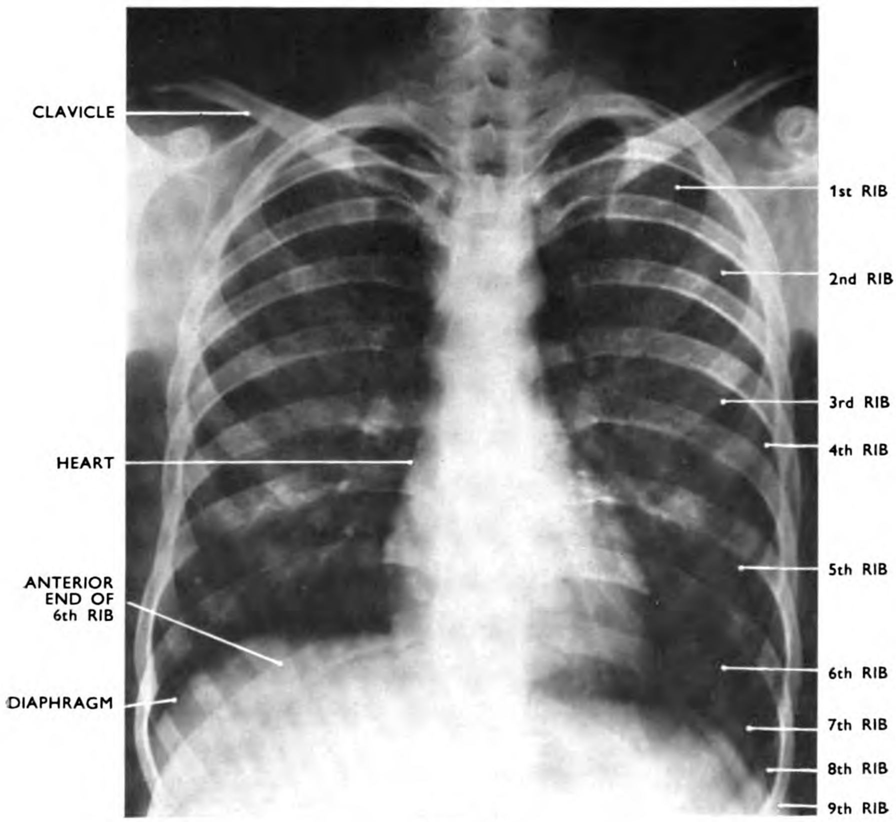


FIG. 169
Upper ribs: postero-anterior radiograph: exposure made on inspiration.

Upper Ribs : Postero-anterior Radiographs (Figs. 169 and 170)

These radiographs demonstrate the anterior ends of the upper ribs well, since they are close to the film : the posterior ends of the ribs are also visible where not obscured by the shadow of the heart and great vessels, but definition is a little poorer owing to their distance from the film. Overlap of the ribs in the axillary line obscures their detail, and an oblique radiograph is more satisfactory in the examination of this area.

Two radiographs of the same subject are given for comparison, one taken on inspiration and the other on expiration. On inspiration the anterior ends of the sixth ribs are visible at diaphragmatic level, whilst on expiration the fifth rib is the lowest visible.

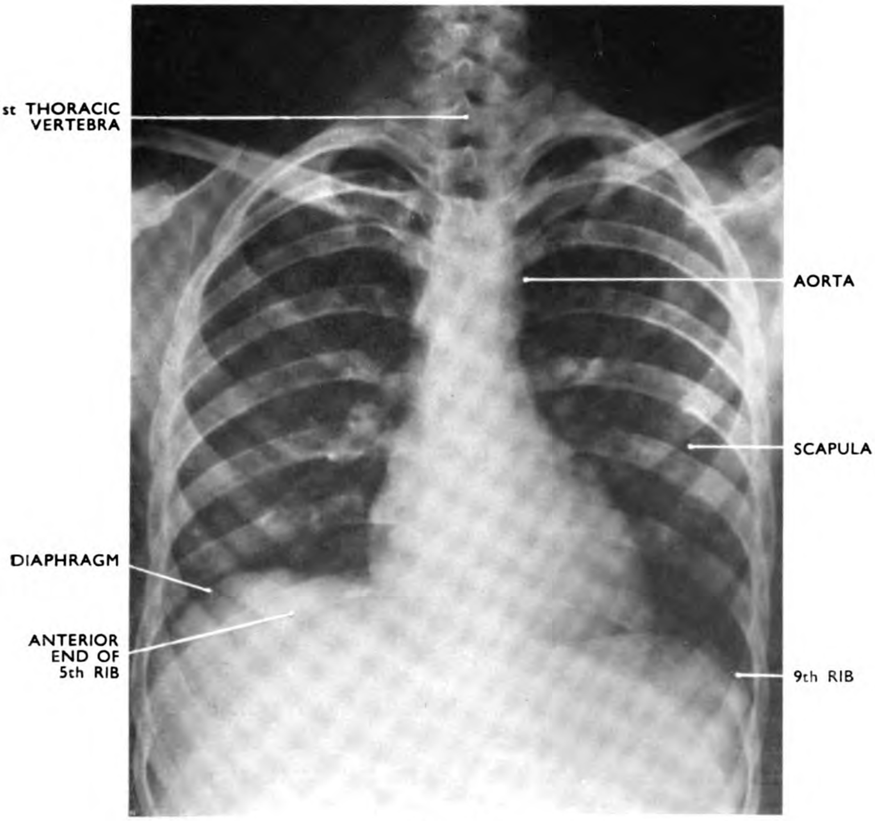


FIG. 170

Upper ribs : postero-anterior radiograph : exposure made on expiration.

Ribs : Oblique Radiograph (Fig. 171)

This radiograph is taken with the trunk rotated 45° from the antero-posterior position, so that the ribs of the side under examination are nearest the film. The whole length of the upper seven or eight ribs can be seen, although the anterior ends are foreshortened and the heads overshadowed by the thoracic

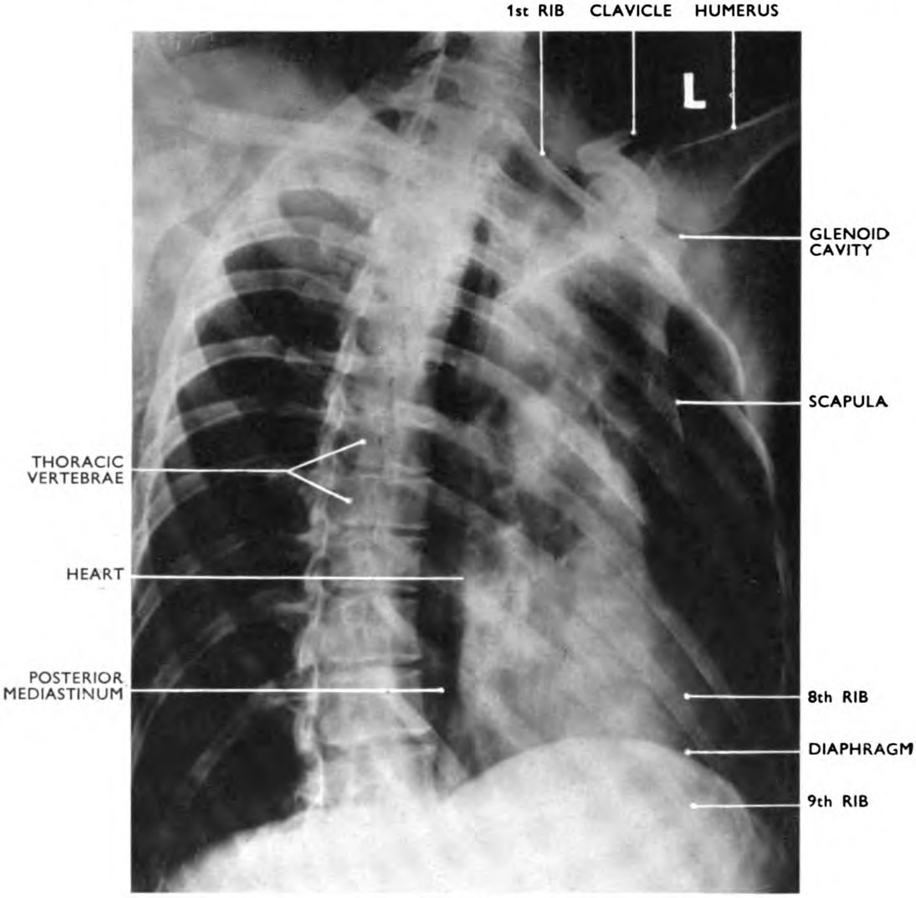


FIG. 171
Ribs: oblique radiograph.

vertebral bodies. The lower ribs are partly obscured by the dense shadows of the abdominal viscera below the left dome of the diaphragm, and must therefore be examined separately with greater radiographic exposure. Rotation of the trunk also separates the shadow of the heart and great vessels from that of the vertebral column, so that the posterior ends of the ribs appear in the transradiant posterior mediastinum. Elevation of the arm prevents superimposition of the humerus on the ribs, but it is impossible to prevent superimposition of the scapula on the upper six ribs.

Articulation of the heads of the ribs with two adjacent vertebral bodies can

be seen, particularly in the case of the eighth and ninth ribs, but it is not so evident in the upper ribs, owing to obliquity. The tubercles of the ribs and the costo-transverse articulations on the side nearest the film (in this case the left side) cannot be identified, but they can be seen on the contralateral side. It should be noted that ribs increase in obliquity from above downward, so that the ninth is the most oblique and that the seventh rib is the largest.

Cervical Ribs : Antero-posterior Radiograph (Fig. 172)

When the costal element of the seventh cervical vertebra develops as a cervical rib, the condition may be unilateral or more commonly bilateral. On an antero-posterior radiograph cervical ribs are seen immediately above the transverse processes of the first thoracic vertebra and posterior ends of the first ribs: they may be long and slender or short and pointed, as in the radiograph shown here. The anterior extremity of the rib may be cartilaginous or may be connected to the sternum by a band of fibrous tissue, so that the true length of the costal element is not always radiographically demonstrable. If a long cervical rib is present it may irritate the lower part of the brachial nerve plexus which runs over it, and so produce symptoms in the hand.

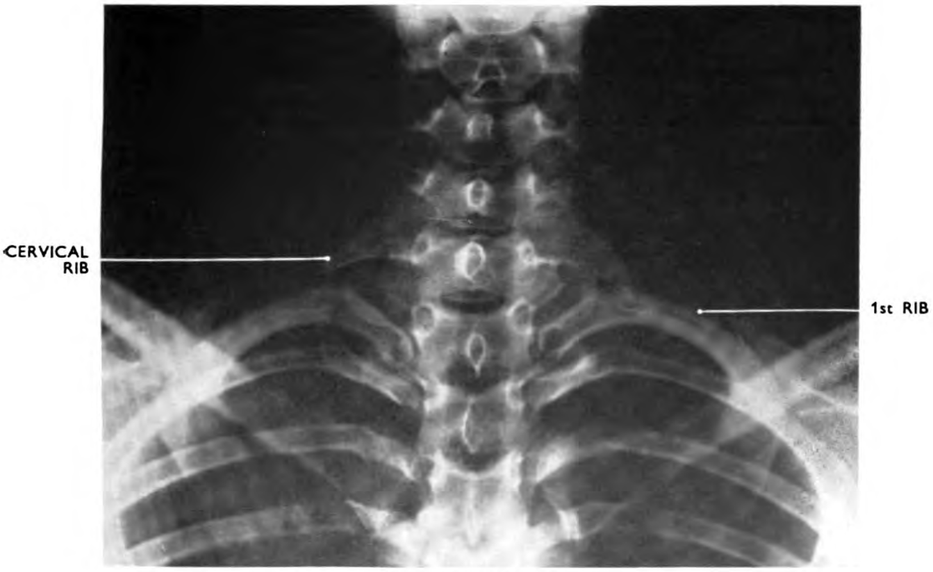


FIG. 172
Cervical ribs: antero-posterior radiograph.

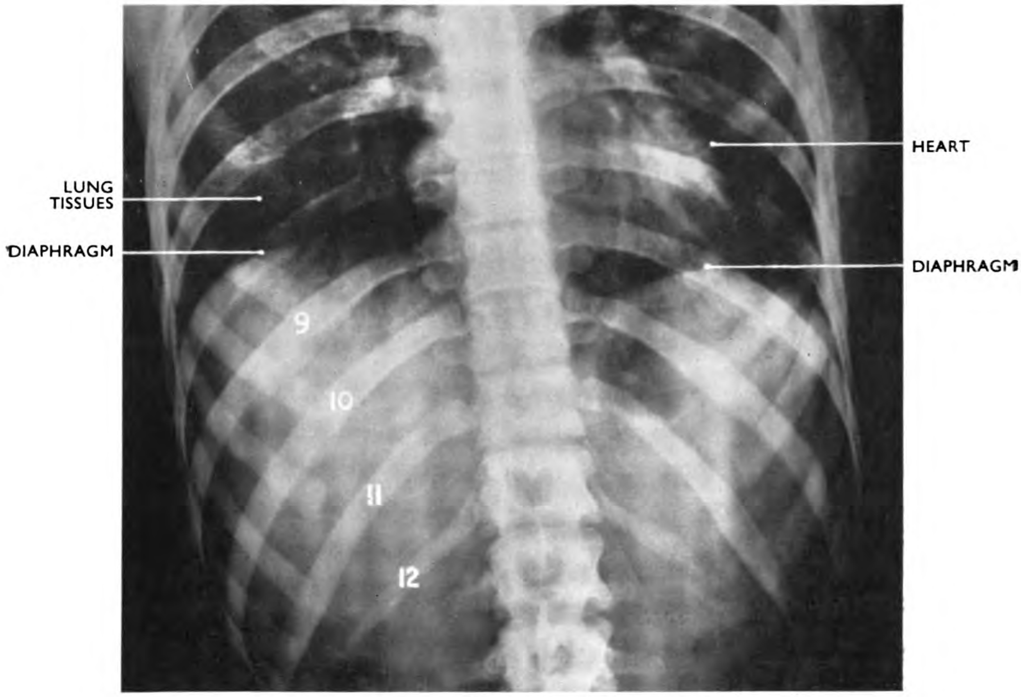


FIG. 173
Lower ribs: antero-posterior radiograph: exposure made on expiration.

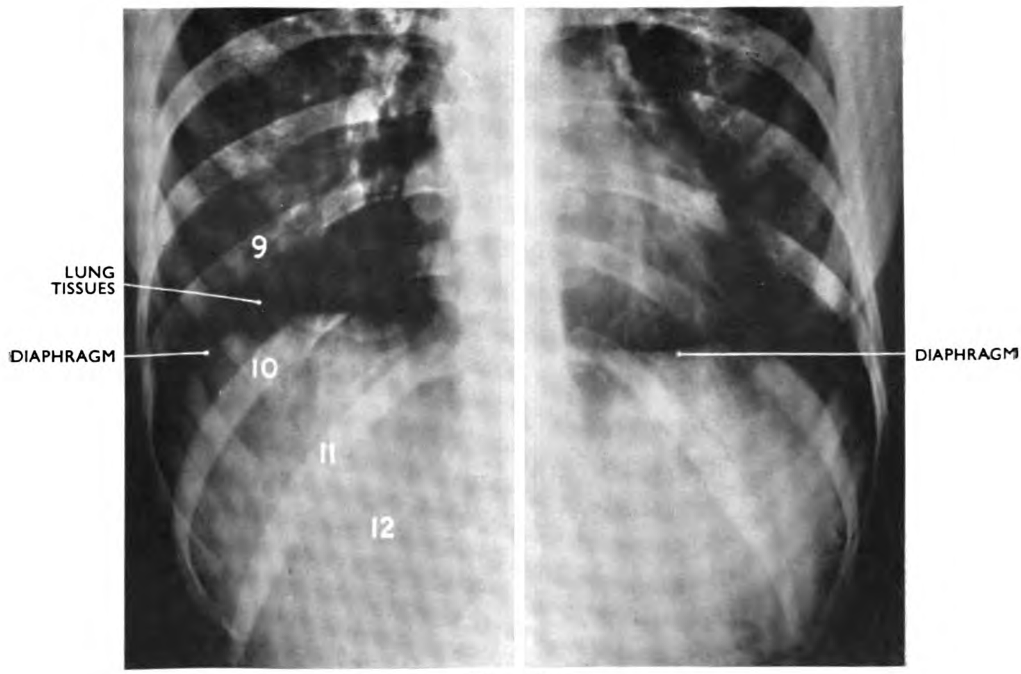


FIG. 174
Lower ribs: antero-posterior radiograph: exposure made on inspiration.

Lower Ribs : Antero-posterior Radiographs (Figs. 173 and 174)

Two radiographs of the same subject are given for comparison to show the use which can be made of the movement of the diaphragm in the examination of the lower ribs. In the radiograph taken on expiration, the diaphragm is high and the lower ribs, including the ninth pair, are clearly visible: on inspiration with the diaphragm at its lowest level, the resultant radiograph does not demonstrate the lower ribs so clearly.

In Figure 173 the ninth and tenth pairs of ribs are seen to articulate with the demi-facets of the eighth and ninth, and ninth and tenth vertebrae respectively; they also articulate with the upper surfaces of the transverse processes of the numerically corresponding vertebrae. The eleventh and twelfth ribs articulate only with the bodies of their respective vertebrae; the transverse processes of the last two vertebrae are small and the costo-transverse joints absent. Small lumbar ribs are occasionally present and articulate with the body of the first lumbar vertebra only.

Ossification of the Sternum and Ribs (Figs. 175 and 176)

Ossification of the sternum (Fig. 175) takes place from six centres—one for the manubrium, four for the body (*i.e.*, one for each segment) and one for the xiphoid process: the centre for the xiphoid process appears after the third

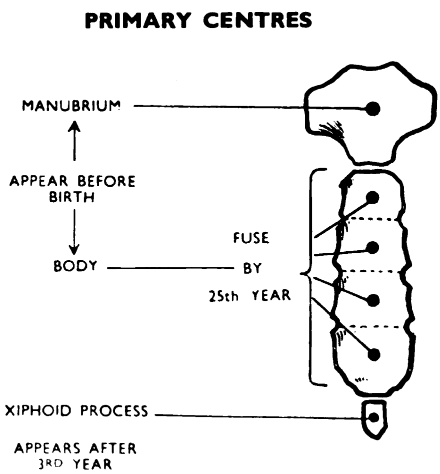


FIG. 175
Ossification of the sternum.

year, but the others are present at birth. Fusion of the centres for the body takes place after puberty, but the manubrium and xiphoid process persist as separate bones in adult life.

A typical rib ossifies from one primary centre and three secondary centres (Fig. 176). The primary centre for the shaft appears early in intrauterine life:

the three secondary centres develop about puberty, and consist of a centre for the head and one for each area of the tubercle. Fusion of the centres takes place about the twentieth year. The first rib is atypical in that it has three

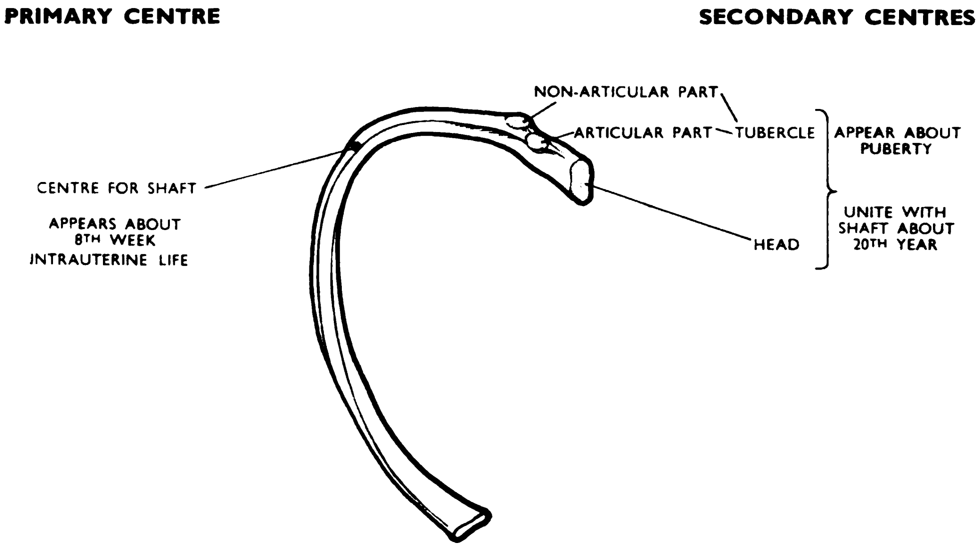


FIG. 176
Ossification of a typical rib.

centres—a primary centre for the shaft, a secondary centre for the head and only one secondary centre for the tubercle. As the eleventh and twelfth ribs do not possess tubercles, there are only two centres—one for the shaft and one for the head.

CHAPTER VII

THE SKULL

IT is important that the student should be more familiar with the skull as a whole than with a detailed knowledge of the individual bones. Accordingly the main features of the articulated skull will be described as its external surface is viewed from different aspects, and as the interior of the cranial cavity is seen when the skull cap has been removed: examination of the sagittal section of the skull will also be found to be of great value. Some of the bones which are particularly important will be individually considered in greater detail on page 215.

The skull is the skeleton of the head. It consists of a large number of bones locked together at irregular joints called sutures: the only movable bone is the lower jaw or mandible.

The student should first identify the following main landmarks (Figs. 177, 178 and 179) as they will be frequently used in subsequent descriptions:—

1. The orbits are two large cavities, one on either side of the midline, in the front of the skull: they contain the eyeballs.

2. The anterior nasal opening is the pear-shaped opening between and below the orbits; this opening leads into the two nasal cavities which are separated by a midline bony septum.

3. The external auditory meatus is the small hole in the lower lateral part of the skull.

4. The zygomatic arch is a narrow bony bridge on the side of the skull between the orbit and the external auditory meatus.

5. The foramen magnum is the large oval opening in the posterior part of the under surface of the skull: it transmits the lower part of the brain stem.

6. The bony palate is the horseshoe-shaped shelf of bone on the anterior part of the under surface of the skull: it is part of the upper jaw and separates the nasal cavities from the oral cavity (mouth). (Fig. 183, p. 206.)

7. The internal surface of the base of the skull is divided by well-defined bony ridges into three compartments, known as anterior, middle and posterior cranial fossae.

The bones of the skull can be divided roughly into two groups:—

(*a*) The bones of the upper part of the skull or cranium (brain box); these bones surround and protect the brain.

(*b*) The facial bones, including the lower jaw, which are situated below the front of the cranium. They enclose the cavity of the mouth (oral cavity) and between them and the lower surface of the front of the cranium lie the orbits and the nasal cavities.

The Bones of the Cranium

In Figures 177, 178 and 179 the following eight bones will be seen to form the cranium.

The **frontal bone** is a large single bone which forms the prominence of the forehead and the anterior part of the base of the cranial cavity. The frontal

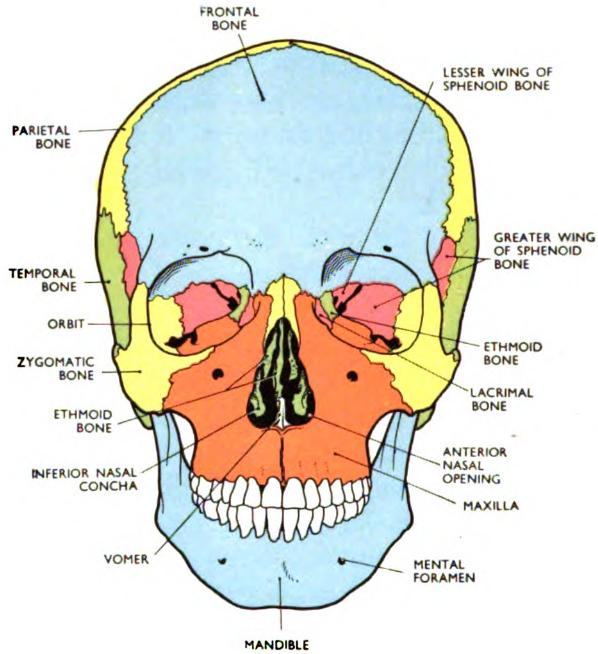


FIG. 177
Diagram of the skull : anterior aspect.

sinuses are situated in this bone above the anterior margins of the orbits and bridge of the nose.

The **parietal bones**—two in number—are placed one on either side of the midline to form a large part of the top and sides of the vault of the cranium.

The **sphenoid bone,** a single bone, extends across the base of the cranium behind the frontal bone. Its outer extremities (greater wings) form a small portion of the lower side walls of the cranium.

The **occipital bone** forms the posterior part of the base and vault of the cranium. Articulation between the skull and the vertebral column takes place through this bone, and it also transmits through the foramen magnum the lower part of the brain stem.

The **temporal bones** are placed one on either side of the cranium. Each bone consists of four constituent parts fused together: the petromastoid part forms a portion of the base of the cranium and is wedged in between the sphenoid bone in front and the occipital bone behind: the squamous part

forms a portion of the lower side wall of the cranium, including the posterior part of the zygomatic arch. The two remaining parts, the tympanic plate and the styloid process, are small and are situated around the external auditory meatus. The temporal bone contains the organs of hearing and balance.

The **ethmoid** is a single, small, lightly constructed bone. It forms the upper part of the nasal cavity and the greater part of the medial wall of each orbit: its upper surface lies in the anterior part of the base of the cranium between the orbital roofs.

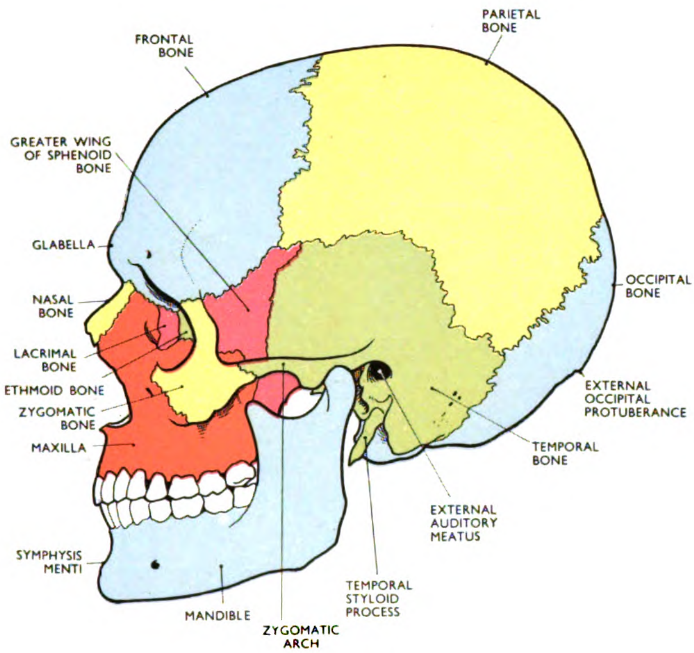


FIG. 178
Diagram of the skull : lateral aspect.

The Bones of the Face (Figs. 177, 178 and 179)

The principal bones are those of the upper and lower jaw. The **upper jaw** is formed by the two maxillae: they are joined together in the midline to complete the greater part of the anterior nasal opening, and on their under surface each sends a horizontal shelf of bone inward to form the greater part of the hard palate which separates the nasal and oral cavities. Each maxilla also forms a part of the floor of the orbit and contains a maxillary air sinus.

The **lower jaw or mandible** is the only movable bone of the skull. The head of each side of the mandible articulates with the mandibular fossa on the base of the skull immediately in front of the external auditory meatus to form the temporo-mandibular joint.

In addition there are a number of smaller bones, as follows :—

The **nasal bones** are two small bones which complete the bridge of the nose and the upper part of the anterior nasal opening.

The **zygomatic bones,** one on either side, join the maxillae to the frontal

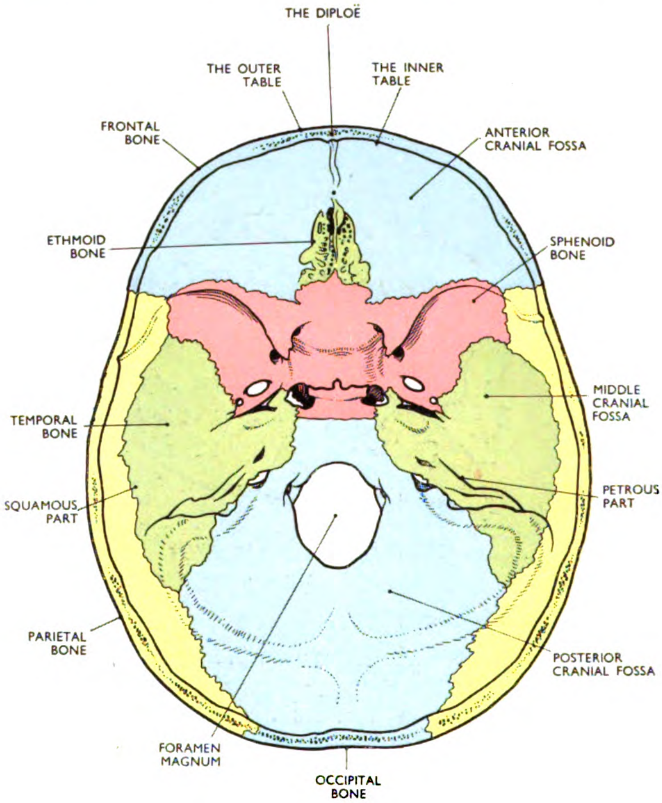


FIG. 179
Diagram of floor of cranial cavity.

bone and complete the outer wall of the orbits. They also form the prominence of the cheeks.

The **lacrimal bones** are two very small bones which lie one in the anterior part of the medial wall of each orbit.

The **vomer** is a thin flat bone which forms the lower and posterior part of the nasal septum.

The **inferior nasal concha** is a small curved bone which projects from the lower part of the lateral wall of each nasal cavity.

The **palatine bones** lie in the posterior part of the nasal cavity. They form the posterior extremity of the bony palate and a small part of the lateral wall of the nasal cavities.

EXAMINATION OF THE SKULL AS A WHOLE

FRONTAL ASPECT (Fig. 180)

As seen from in front the skull appears slightly wider above than below.

The following bones form the main structure: the frontal bone has a convex anterior surface and forms the dome of the forehead and the upper margins of the orbits; the zygomatic bone forms the prominence of the cheek and

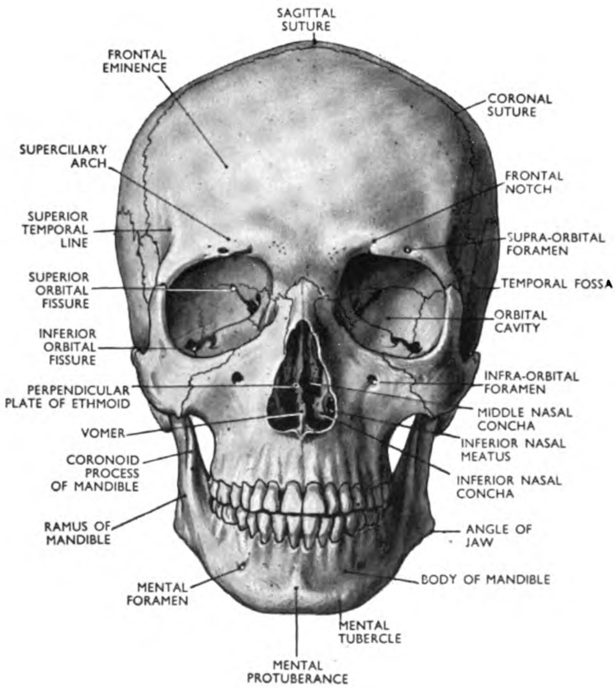


FIG. 180
Skull : frontal aspect.

completes the lower margin of the orbit: the two maxillae together form the upper jaw, the remainder of the lower and medial margins of the orbits, and enclose the anterior nasal opening. Note that there are also a number of smaller bones which take part in the formation of the anterior nasal opening and the orbits. The lower jaw or mandible will be discussed later.

The superciliary arch is the rounded ridge above the inner part of each supra-orbital margin: the region above the bridge of the nose and between these arches is known as the glabella. A frontal sinus lies in each side of the frontal bone behind the superciliary arch; it is variable in size and may extend posteriorly into the roof of the orbit. The sinus communicates with the nasal cavity by a short channel.

Near the inner end of each supra-orbital margin is the supra-orbital notch which transmits nerves and vessels: in some skulls this notch may be bridged over and converted into a foramen; medial to this notch there may be a second or frontal notch. The supra-orbital margin ends laterally in a prominent downward projection, the zygomatic process, so called because it articulates with the zygomatic bone. A portion of the frontal bone projects downward between the orbits; it is called the nasal part, and articulates with the nasal bones at the nasion and with the frontal processes of the maxillae.

The **maxillae** are two roughly pyramidal bones which meet in the midline: they each possess a nasal notch, which forms the lateral and lower margins of the anterior nasal opening when the two bones are articulated. A sharp midline bony projection, called the anterior nasal spine, is present on the lower margins of this opening. The part of the maxilla below the level of the nasal opening is called the alveolar process, and contains the roots of the upper teeth. A prominent foramen is present on the anterior surface of the maxilla a quarter of an inch below the infra-orbital margin; this infra-orbital foramen transmits nerves and vessels to the skin of the front of the face. Each maxilla is hollowed out to contain the maxillary antrum, the largest of the air sinuses, which communicates with the nasal cavity by a small opening, the maxillary hiatus.

The **nasal cavity** extends backward between the maxillae and orbits on either side, and the anterior part of the base of the cranium above: the hard palate forms its floor. It is divided into two separate cavities by a median partition or septum. The anterior part of the nasal septum is composed of cartilage and is not present in the dry skull, but the bony septum can be seen: the upper part is formed by the perpendicular plate of the ethmoid and the lower posterior part by the vomer. The lateral walls of the nasal cavities are uneven, because three thin curved bones called conchae project from them into the cavity: beneath each concha is a channel or meatus, and there are therefore the superior, middle and inferior conchae and nasal meatuses on each side. On the front view of the skull the bony nasal septum and the middle and inferior conchae are visible, but the superior concha is too high up and too far back to be seen.

The Orbits (Fig. 181)

The orbits are pyramidal-shaped cavities. Each orbit contains the eyeball and its muscles, nerves and blood-vessels, and also the lacrimal gland. They are wide in front and narrow to an apex which is directed backward and slightly medially. The orbital margins have already been described.

The **roof** of the orbit is formed mainly by the thin orbital plate of the frontal bone which separates the orbit from the anterior cranial fossa. The lesser wing of the sphenoid forms the extreme posterior end of the roof, and

through this bone the optic canal enters the apex of the orbit and transmits the optic nerve and ophthalmic artery.

The **medial wall** is formed chiefly by the ethmoid bone which, as previously stated, lies between the orbits and forms the roof of the nasal cavities. The ethmoid contains the ethmoid air cells or sinuses and they are separated from the orbits only by a thin plate of bone. The lacrimal bone is a very small bone

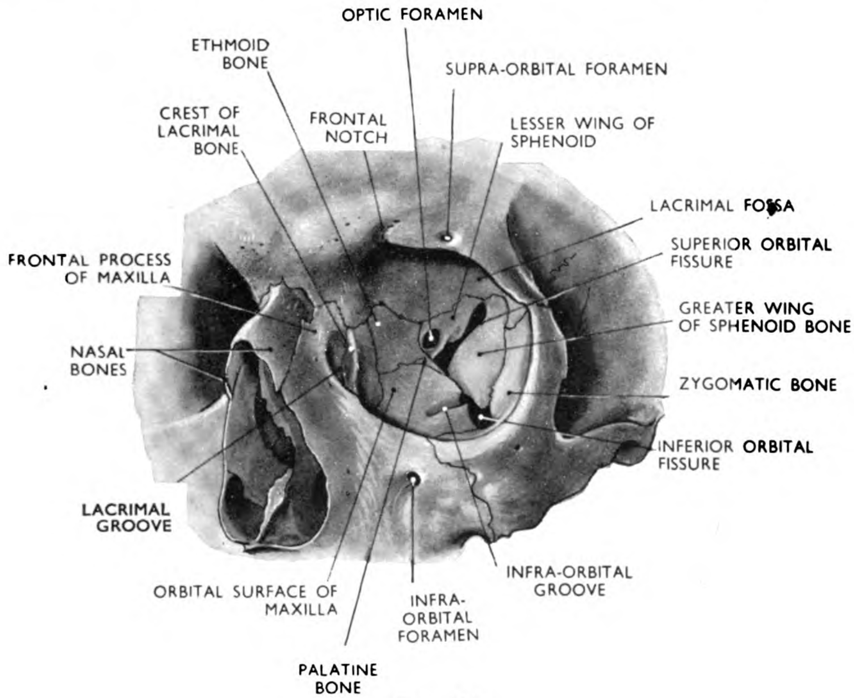


FIG. 181
The left orbit.

placed in the anterior part of the medial wall. Together with the frontal process of the maxilla the lacrimal bone forms a groove which lodges the lacrimal sac and communicates by the naso-lacrimal canal with the inferior meatus of the nose.

The **lateral wall** consists of the greater wing of the sphenoid posteriorly and the zygomatic bone anteriorly. The superior orbital fissure is a gap between the lateral wall and roof near the apex of the orbit; through it pass the nerves from the middle cranial fossa which supply the muscles of the eyeball.

The **floor** is formed by the maxilla and the zygomatic bone. Between the posterior part of the floor and the lateral wall is the inferior orbital fissure. Note also the infra-orbital groove which runs forward on the floor to become the infra-orbital canal and opens on the anterior surface of the maxilla at the infra-orbital foramen: it transmits the infra-orbital nerve to supply the skin of the face adjoining the side of the nose.

LATERAL ASPECT OF SKULL (Fig. 182)

The lateral aspect of the skull may be divided into two parts by an imaginary line drawn through the supra-orbital margin and the external auditory meatus. This line represents the general plane of the base of the cranium and is inclined at a slight angle to the horizontal. On and above this line lies the brain box or cranium, and suspended from the front of the base are the facial bones.

Two important sutures cross the vault of the cranium; the coronal suture

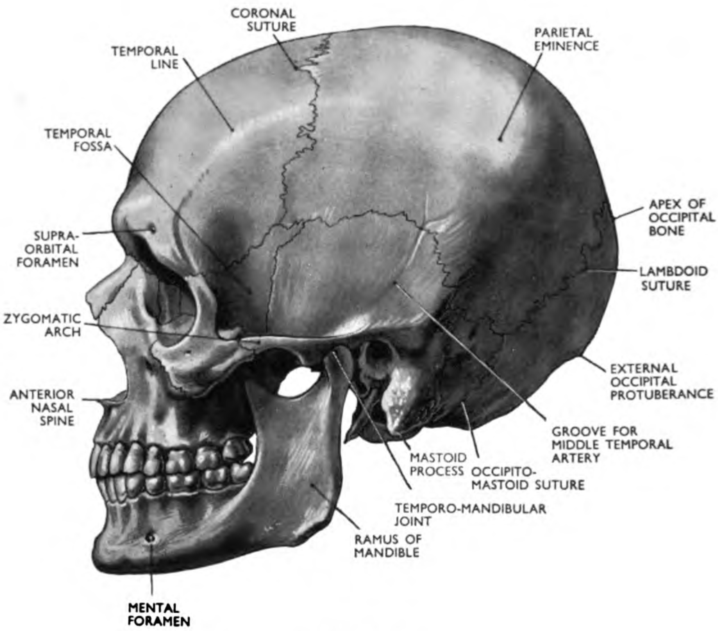


FIG. 182
Skull: lateral aspect.

separates the frontal from the parietal bones and the lambdoid suture lies between the parietal and occipital bones. The coronal and lambdoid sutures are connected in the midline by the sagittal suture which therefore lies between the two parietal bones. The meeting point of the coronal and sagittal sutures is called the bregma and is occupied in infancy by a diamond-shaped membranous gap called the anterior fontanelle; due to bone growth this fontanelle is normally closed by the end of the second year. The junction of the sagittal and lambdoid sutures is known as the lambda; a small fontanelle, the posterior fontanelle, is present in this situation at birth but closes soon after.

Above the bridge of the nose the superciliary arch is seen in profile and the zygomatic process of the frontal bone can be identified on the lateral margin

of the orbit. Note also the temporal line which commences at the zygomatic process and arches upward and backward across the parietal bone to end by joining the supramastoid crest above the mastoid process. The **temporal fossa** is the area bounded above by the temporal line and below by the zygomatic arch. Four bones form the floor of this fossa, the frontal bone and greater wing of the sphenoid in front, and the parietal bone and squamous part of the temporal bone behind. The fossa gives attachment to the temporalis muscle which passes under the zygomatic arch to be inserted into the coronoid process of the mandible; this muscle is one of the principal muscles of mastication. The **infratemporal fossa** is the area below the zygomatic arch. It is bounded in front by the posterior surface of the maxilla, and is partly hidden from view by the ramus of the mandible. It communicates with the temporal fossa through the wide gap that separates the zygomatic arch from the side wall of the cranium.

The **zygomatic arch** is a thin bony arch formed in front by the zygomatic bone and behind by the zygomatic process of the temporal bone. It can be felt through the skin. An eminence is present on the under surface of the arch in front of the mandibular fossa: this is known as the articular tubercle and is a part of the anterior root of the zygoma which passes medially to join the side wall of the cranium. The posterior part of the arch, or posterior root, extends backward over the external auditory meatus and becomes continuous with the supramastoid crest.

The **external auditory meatus** consists of a short outer cartilaginous portion and an inner bony portion which forms two-thirds of its total length. The bony portion only is visible in the dried skull and is about fifteen millimetres in length. It is directed forward and inward and ends at the tympanic membrane which separates the external ear from the middle ear or tympanic cavity. The roof and upper half of the posterior wall of the meatus is formed by the squamous part of the temporal bone; the remainder of the circumference of the wall is formed by the tympanic plate of the temporal bone. Immediately above and behind the upper margin of the external opening of the bony meatus is a small depression, the suprameatal triangle; this landmark is of importance in surgery, since it is the surface guide to the mastoid antrum.

The **styloid process** is a slender bony projection below and medial to the external auditory meatus. It is seen projecting from the cranial base between the mandible and the mastoid process.

The **mastoid process** is the conical projection behind the external auditory meatus. It gives attachment to some of the muscles of the neck and contains air cells, which communicate with the tympanic cavity: the largest of the air cells is called the mastoid antrum.

THE UNDER SURFACE OF THE SKULL (Fig. 183)

The under surface of the skull is very irregular and presents a large number of foramina and bony projections. As there are no natural boundary lines it is convenient to divide the whole area into anterior, middle and posterior parts by two transverse lines running through the posterior margin of the hard palate, and the anterior margin of the foramen magnum.

The Anterior Part

The anterior part is formed by the **hard palate** which constitutes the roof

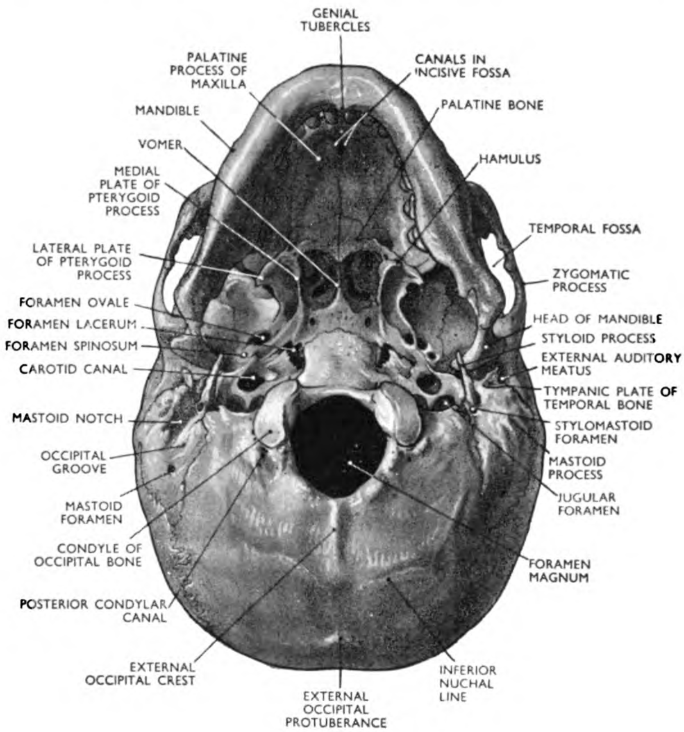


FIG. 183
Skull : under surface.

of the mouth and the floor of the nasal cavities. It is bounded in front and at the sides by the alveolar processes of the maxillae. The anterior two-thirds is formed by the palatine processes of the maxillae, and the posterior one-third by the horizontal parts of the palatine bones. A midline and a transverse suture can therefore be seen on the hard palate. At the anterior end of the midline suture behind the incisor teeth there is a small fossa, the incisive fossa; the lateral incisive canals open into the fossa and transmit nerves from the nasal cavities to the mouth. The posterior margin of the hard palate is thin

and sharp and the soft palate is attached to it : in the midline there is a small projection directed backward called the posterior nasal spine.

The **alveolar processes** of the maxillae form the thick horseshoe-shaped ridges on the anterior and lateral margins of the hard palate; they provide the sockets for the roots of the sixteen teeth of the upper jaw. If the teeth are all present, there are from front to back on each side, two incisors, one canine, two premolars and three molars. The posterior end of the alveolar process behind the third molar tooth is rounded and prominent and is known as the maxillary tuberosity.

The Middle Part

The middle third of the under surface of the skull extends from the posterior margin of the hard palate to the anterior margin of the foramen magnum.

The **posterior nasal openings** (choanae) lie between the posterior margins of the hard palate and the base of the cranium. They are separated in the midline by the vomer, a thin flat bone which forms the posterior margin of the nasal septum. The pterygoid processes project downward from the base of the cranium, behind the maxillae and on either side of the posterior nasal openings; they are parts of the sphenoid bone. Each pterygoid process consists of a medial and a lateral plate, which enclose between them the pterygoid fossa. The medial pterygoid plate forms the lateral wall of the posterior nasal opening, and a small hook, the hamulus, projects downward and laterally from its lower margin.

Behind the posterior nasal openings the body of the sphenoid and the basilar part of the occipital bone form a broad bar of bone extending to the foramen magnum; these two bones are separated by a cartilaginous plate in early life, and bony fusion usually takes place about the twenty-fifth year. The area lateral to this central bar of bone is formed in front by the greater wing of the sphenoid, and on the outer side by the squamous part of the temporal bone, which bears the mandibular fossa and articular tubercle. The petrous temporal bone projects inward and medially in the form of a wedge between the sphenoid and occipital bones. Two important foramina are present in the greater wing of the sphenoid on an oblique line between the lateral pterygoid plate and the mandibular fossa: the foramen ovale is the large oval anterior opening, and transmits the mandibular nerve, whilst behind it is a much smaller foramen, the foramen spinosum, through which the middle meningeal vessels enter the middle cranial fossa. The foramen lacerum lies medial to the foramen ovale, between the apex of the petrous temporal and the sphenoid bone ; it is an irregular opening, partially closed in life by cartilage. The carotid canal lies a short distance postero-lateral to the foramen lacerum; the internal carotid artery emerges from this canal into the middle cranial fossa and crossing the foramen lacerum turns upward. The cartilaginous part of the auditory tube (pharyngo-tympanic tube) lies in a groove between the carotid canal and the

foramen ovale, and opens into a small bony canal which leads into the tympanic cavity. Lying immediately behind the carotid canal, between the petrous temporal and occipital bone, is the jugular foramen, which transmits the sigmoid sinus to become the internal jugular vein. At the base of the styloid process, which lies lateral to the jugular foramen, is the small but important stylomastoid foramen; through this foramen the facial nerve emerges to supply the muscles of expression of the face. Behind this foramen, note the deep groove, the mastoid notch, on the medial aspect of the mastoid process; it gives attachment to the digastric muscle.

The Posterior Part

The posterior part of the under surface of the skull lies behind the anterior margin of the foramen magnum. It is formed chiefly by the occipital bone. Note the position of the occipital condyles which articulate with the atlas vertebra; they are convex and lie obliquely on either side of the anterior part of the foramen magnum. There are few prominent features on the occipital bone behind the foramen magnum, but the external occipital protuberance is well marked and can be seen in profile on the lateral view of the skull. The external occipital crest and nuchal lines are bony ridges which give attachment to the ligamentatum nuchae and muscles of the neck respectively.

THE CRANIAL CAVITY

The cranial cavity is occupied by the brain. It is lined by the dura mater which is the outer of the three membranes or meninges surrounding the brain. The pia mater is the innermost layer and closely invests the brain substance; between it and the middle layer, the arachnoid, lies the subarachnoid space, in which the cerebrospinal fluid circulates.

The skull cap or roof of the cranial cavity can be removed by a horizontal saw cut, so that the internal or cerebral surface of the cavity is displayed.

The Internal Surface of the Skull Cap

Examination of the cut surface of the bone shows that its thickness varies: it is always thickest in areas most exposed, *e.g.*, the frontal and occipital regions, and thinnest in areas well covered by muscle such as the temporal region. Most cranial bones consist of an inner and an outer table of compact bone, separated by cancellous bone containing red bone marrow (diploë) and diploic veins. The diploic veins are very variable in size and extent, but are usually most prominent in the parietal bones. The sagittal groove extends backward in the midline from the frontal crest to the internal occipital protuberance. A large venous channel, the sagittal sinus, lies in the groove, enclosed in the base of a fold of dura mater, the falx cerebri, which projects downward between the cerebral hemispheres. On either side of the sagittal groove there are

numerous small depressions in the bone for protrusions of the subarachnoid space, called arachnoid granulations: these granulations are found in the vicinity of the large blood sinuses, and through them there is an interchange of fluid between the blood and the cerebrospinal fluid. The inner surface of the bone is also grooved by the middle meningeal artery: the anterior branch of this artery runs upward, behind and roughly parallel to the coronal suture, and the posterior branch extends obliquely upward and backward to the parietal bone. These internal grooves are variable in size, and in some skulls may be almost absent.

The Floor of the Cranial Cavity (Fig. 184)

The floor of the cranial cavity is naturally divided by prominent bony ridges into anterior, middle and posterior fossae; the anterior fossa lies at the highest and the posterior at the lowest level.

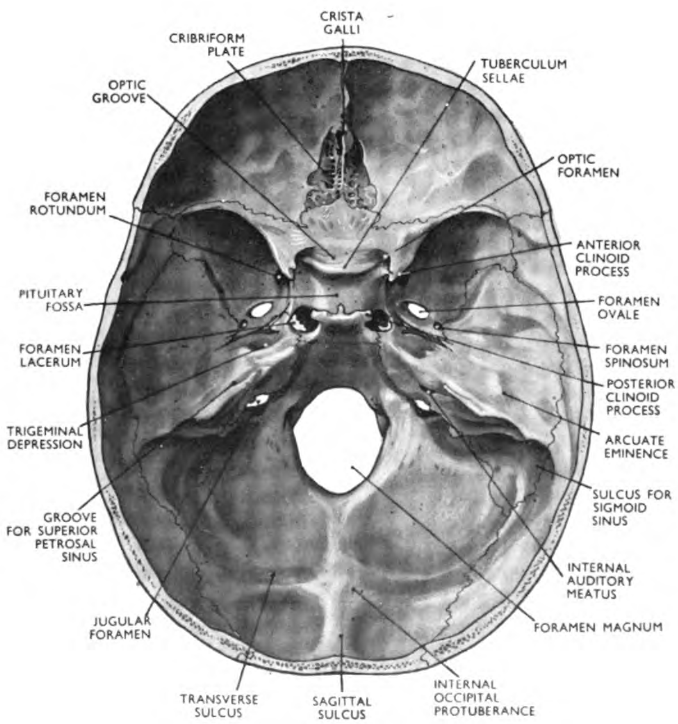


FIG. 184
Floor of cranial cavity.

The Anterior Cranial Fossa

The anterior fossa contains the lower part of the frontal lobes of the brain. The frontal bone forms the anterior and lateral walls; the orbital plate of this bone constitutes the anterior two-thirds of the floor and separates the fossa

above from the orbits below. The posterior margins are formed by the body of the sphenoid centrally and by the lesser wings of the sphenoid on either side. The medial end of each lesser wing projects backward as a prominent process called the anterior clinoid process. The horizontal (cribriform) plate of the ethmoid is interposed in the midline between the orbital plates of the frontal bone, and is perforated by numerous small holes for passage of the olfactory nerves from the nasal cavity. A prominent median crest of bone on the cribriform plate is called the crista galli and gives attachment to the falx cerebri. The frontal sinuses lie in the bone of the anterior wall of the fossa, but may sometimes extend backward into the orbital plate.

The Middle Cranial Fossa

The middle cranial fossa is bounded in front by the posterior borders of the lesser wings of the sphenoid, and behind by the well-defined ridges on the upper surface of the petrous temporal bones and by the dorsum sellae of the sphenoid. It consists of a narrow middle portion and two wide lateral portions, so that it may be likened in shape to a butterfly with outstretched wings. The **middle portion** is formed by the upper surface of the body of the sphenoid and is raised above the level of the lateral portions. The optic foramen lies between the lesser wing and body of the sphenoid, and is directed forward and slightly outward and downward to enter the apex of the orbit; through this canal pass the optic nerve and ophthalmic artery. A transverse groove, the optic groove, is present on the upper surface of the body of the sphenoid between the optic foramina and is bounded posteriorly by a ridge, the tuberculum sellae. Behind, the upper surface of the body of the sphenoid is shaped like a Turkish saddle, and is therefore named the sella turcica. It is bounded in front by the tuberculum sellae and behind by an upward projecting plate of bone, the dorsum sellae; the concavity between these is occupied by the pituitary gland (hypophysis cerebri) and is known as the pituitary or hypophyseal fossa. The upper corners of the dorsum sellae are prominent and are called the posterior clinoid processes. It should be noted that the anterior clinoid processes do not overhang the pituitary fossa, but are situated a short distance lateral to it.

The **lateral parts** of the middle fossa are wide and deep. Each contains the temporal lobe of the brain, and lies in relationship to the orbit in front, the temporal fossa laterally, and the mandibular joint below. The greater wing of the sphenoid forms the anterior part of the floor and a little of the side wall: the squamous part of the temporal bone forms the lateral part of the floor and most of the side wall, whilst the petrous part of the temporal constitutes the posterior part of the floor. The overhanging margin of the lesser wing of the sphenoid forms the anterior boundary, and the upper border of the petrous temporal, the posterior boundary. Note that the lateral part of the fossa communicates with the orbit through the superior orbital fissure, between the lesser and greater wings of the sphenoid. The lesser wing overhangs this

fissure and conceals it from view when the base of the skull is seen from above, but the foramen rotundum, which lies below it and transmits the maxillary nerve, is clearly visible. The foramen ovale can be readily recognised as an oval opening behind the foramen rotundum, and close to its posterior margin is a small opening, the foramen spinosum, through which the middle meningeal artery enters the middle fossa; the subsequent course of this artery laterally across the floor of the middle fossa can usually be followed by the grooves on the surface of the bone. The foramen lacerum opens into the middle fossa at the side of the pituitary fossa, and lies between the apex of the petrous temporal and the body of the sphenoid bone. The carotid artery crosses this foramen, runs along the side of the body of the sphenoid to pass upward under the anterior clinoid process; after sending off the ophthalmic artery, it ends by supplying the frontal, temporal and parietal lobes of the brain. The upper surface of the petrous part of the temporal bone forms the posterior part of the middle fossa, and is devoid of important foramina, but near its apex is a small hollow, the trigeminal depression, which lodges the ganglion of the trigeminal nerve. Half-way between the apex of the petrous temporal and the side wall of the cranium is a small elevation, the arcuate eminence, produced by the superior semicircular canal of the inner ear. Between the arcuate eminence and the side wall of the cranium the bone surface is smooth and is called the tegmen tympani, since it forms the roof of the middle ear (tympanic cavity); long-standing infection of the middle ear may erode this thin layer of bone and spread to the meninges and temporal lobe of the brain.

The Posterior Cranial Fossa

The posterior fossa is the largest and deepest of the fossae and lies over the vertebral column; it contains the hind brain (cerebellum, pons and medulla oblongata). The anterior boundary is formed in the midline by the posterior surface of the dorsum sellae, and on either side by the petrous parts of the temporal bones. The occipital bone forms the floor and the lateral and posterior walls, with the exception of a small but important region at the junction of the anterior and lateral wall, which is formed by the mastoid portion of the temporal bone and where it is grooved by the sigmoid sinus. Note the large oval-shaped foramen magnum in the anterior part of the fossa. It transmits the lower part of the brain stem and its membranes.

Three foramina lie one above the other on the medial part of the anterior wall above the foramen magnum. The lowest foramen is the anterior condylar canal, which is directed forward and outward above the occipital condyles; it transmits the hypoglossal nerve, which supplies the muscles of the tongue. The jugular foramen is the middle of the three foramina, and is large and irregular in shape. It lies in a gap between the occipital and petrous temporal bones, and transmits the sigmoid sinus and the ninth, tenth and eleventh cranial nerves. The highest foramen is the internal auditory meatus, which enters the

posterior surface of the petrous temporal bone obliquely, and runs laterally into the bone to transmit the auditory and facial nerves.

A bony ridge, the internal occipital crest, extends up the occipital bone behind the foramen magnum to end at the internal occipital protuberance. A shallow wide groove, the transverse sulcus, sweeps round the posterior and lateral walls of the fossa from the internal occipital protuberance; it becomes the sigmoid sulcus on the posterior surface of the temporal bone, and ends at the jugular foramen. These sulci contain the transverse and sigmoid sinuses respectively, which form the main venous drainage channel from the brain. The upper part of the sigmoid sinus is only separated from the tympanic antrum by a thin layer of bone, a fact which is of importance in surgical operations on the middle ear.

The posterior fossa is roofed over by a fold of dura mater called the tentorium cerebelli. This is attached posteriorly to the lips of the transverse sulci, where it encloses the transverse sinuses, and anteriorly it is fixed to the petrous temporal and sphenoid bones. The tentorium is joined in the midline above to the falx cerebri, and separates the cerebellum below from the posterior part of the cerebrum above.

SAGITTAL SECTION OF THE SKULL (Fig. 185)

A study of the sagittal section of the skull is of special value in understanding the main features of the lateral radiograph. Note the general configuration of the skull—the base of the cranium is inclined at an angle to the horizontal and the facial bones are suspended from the anterior part of the cranial base. The position of the frontal and sphenoidal sinuses should be noted. The frontal sinuses are situated between the inner and outer tables of the frontal bone behind the superciliary arches. There are two frontal sinuses separated by a complete bony septum which is often deviated to one side and each sinus may be subdivided by incomplete bony septa. These sinuses are very variable in size, and in some skulls may extend not only upward and outward over the superciliary arches, but also backward into the orbital plate of the frontal bone. The sphenoidal sinuses occupy the body of the sphenoid and therefore lie under the sella turcica; the two sinuses are separated by a median septum and are very variable in size. Both the frontal and sphenoidal sinuses open into the nasal cavity, in common with the ethmoidal and maxillary sinuses.

The area of the base of the cranium behind the sella turcica slopes downward from the dorsum sellae to the anterior margin of the foramen magnum and is known as the clivus. The dorsum sellae and the upper part of the clivus is formed by the body of the sphenoid and the lower part by the basilar part of the occipital bone. These two parts are separated in early life by a cartilaginous plate and bony fusion usually takes place about the twenty-fifth year.

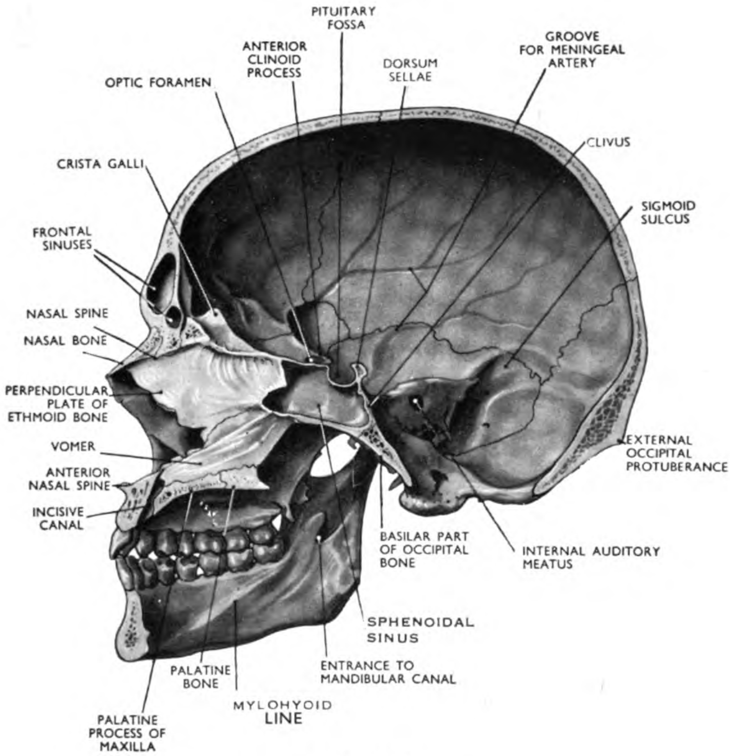


FIG. 185
Sagittal section of the skull.

The Nasal Cavity (Figs. 185 and 186)

The external nose is composed largely of cartilage and is therefore missing from the dry skull. It forms the anterior part of the nasal cavity. The anterior and posterior bony openings of the nasal cavity have already been described. The bony nasal septum, composed of the perpendicular plate of the ethmoid above and the vomer below (Fig. 185), divides the nasal cavity into two parts. The roof and the lateral wall of each cavity are of special interest.

The **roof** is very narrow and is formed from before backward by the nasal, frontal, ethmoid and sphenoid bones. The cribriform (horizontal) plate of the ethmoid separates the roof from the anterior cranial fossa, and through its numerous openings pass the branches of the olfactory nerve from the mucous membrane in the upper part of the nasal cavity. The body of the sphenoid and the sphenoidal sinuses lie between the posterior part of the nasal roof and the sella turcica region of the middle cranial fossa.

The **lateral wall** (Fig. 186) is composed of a number of bones, but the chief feature is the presence of three projecting nasal conchae; each consists of a thin bony plate curving downward to form the roof of a channel known as a

meatus. The inferior concha is the largest; it is a separate bone and extends almost the full length of the lateral wall, overlying the inferior meatus, into which the nasolacrimal canal opens. The superior and middle conchae are parts of the ethmoid bone and form the roofs of the superior and middle meatuses respectively, into which the ethmoid sinuses open.

The **maxillary sinus** occupies the body of the maxilla; it lies lateral to the lower half of the nasal cavity and opens into the middle meatus. It is important

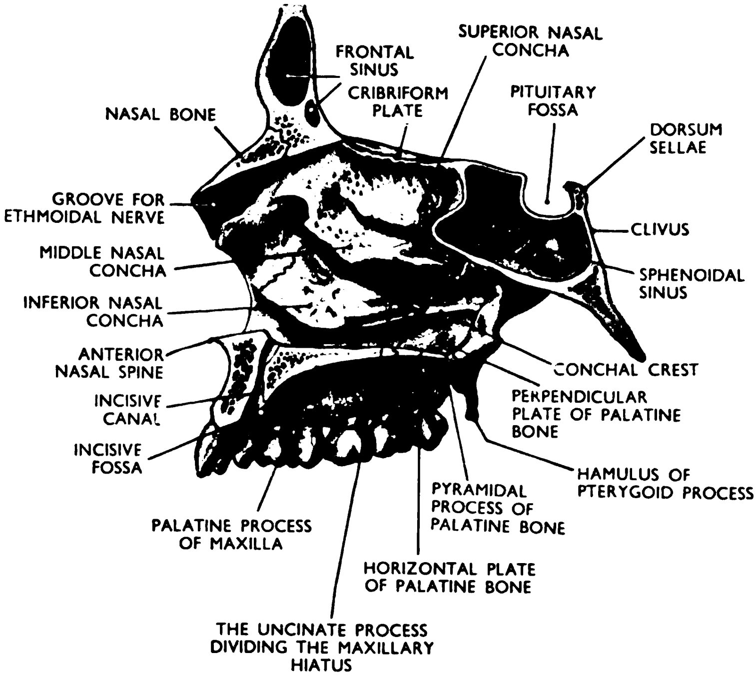


FIG. 186
Sagittal section showing lateral wall of nasal cavity.

to note that the opening of the sinus lies near its roof, so that fluid may collect in the sinus following infection: this is uncommon in the other sinuses, which usually open into the nasal cavity from their lowest point. The **ethmoidal sinuses** lie in each side of the ethmoid bone, between the orbit and the nasal cavity, and are divided into three groups—anterior, middle and posterior; the posterior group opens into the superior meatus, whilst the middle and anterior groups open into the middle meatus. The **frontal sinus** usually opens directly into the middle meatus, but may share an opening with the anterior ethmoidal sinus. The **sphenoidal sinus** opens into a small space (the spheno-ethmoidal recess) above and behind the superior concha.

The **floor** of the nasal cavity is formed by the hard palate, which separates it from the mouth. The construction of the hard palate has already been described.

THE INDIVIDUAL BONES OF THE SKULL

Temporal Bone and Auditory Apparatus

The temporal bone is of great importance to radiographers as radiographic examination of this complex bone is a routine method of investigation of suspected disease of the ear. It is developed from four separate elements—the squamous part, the petromastoid part, the tympanic plate and the styloid process; these elements fuse together to form one bone in the adult. The petromastoid part may be subdivided into petrous and mastoid portions.

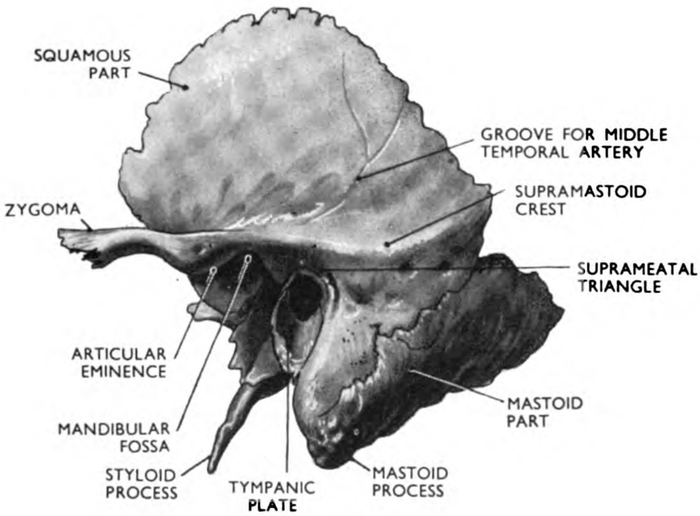


FIG. 187
Temporal bone : lateral aspect.

The **squamous part** (Fig. 187) forms part of the lateral wall of the cranium and the postero-superior part of the external auditory meatus; it includes the zygomatic process (zygoma) and the adjacent articular tubercle and mandibular fossa. It is separated from the mastoid part by a suture situated below the supramastoid crest; this suture may still be visible in the adult, although it is often obliterated when fusion of the individual parts of the temporal bone takes place. The squamous part articulates in front with the greater wing of the sphenoid and above with the parietal bone, where, owing to the bevelled suture, there is considerable overlap of the two bones.

The **mastoid part** is the posterior part of the temporal bone and articulates behind with the occipital bone. It consists of an upper part, containing a large air cell called the mastoid antrum, and a lower conical projection, the mastoid process.

The **petrous part** forms a portion of the base of the cranium and consists of a wedge of dense bone directed forward and medially between the sphenoid and occipital bones. Its upper surface forms the posterior part of the middle cranial fossa and the posterior surface forms the anterior wall of the posterior cranial fossa. The inferior surface can be seen on the under surface of the skull. The main feature of the upper surface is the arcuate eminence under which lies the superior semicircular canal (Fig. 188); between this eminence and the side wall of the cranium is the tegmen tympani or roof of the tympanic cavity and mastoid antrum. The upper surface is separated from the posterior surface by a well-defined ridge, the superior border, often grooved by the

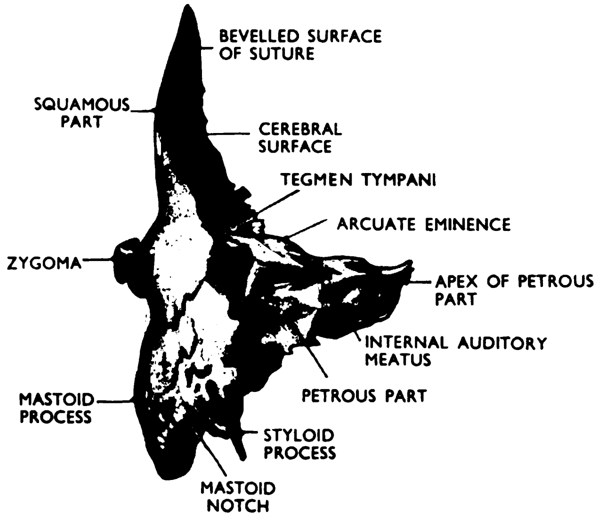


FIG. 188
Temporal bone : posterior aspect.

superior petrosal sinus. The posterior surface shows the opening of the internal auditory meatus (Fig. 188), through which pass the auditory and facial nerves. It should be noted that the facial nerve emerges through the stylomastoid foramen on the under surface of the bone (Fig. 183); on this surface note also the carotid canal and the jugular foramen.

The **tympanic plate** is a thin curved plate of bone which forms the floor, anterior wall and lower half of the posterior wall of the external auditory meatus (Fig. 187). It lies between the squamous and mastoid parts and envelopes the root of the styloid process. The mandibular fossa lies immediately in front of the tympanic plate.

The **styloid process** emerges from the inferior surface of the tympanic plate. It gives attachment to some of the small muscles of the neck and the stylohyoid ligament. The stylomastoid foramen lies behind its base.

The Auditory Apparatus

The ear is divided into three parts—the external ear, the middle ear (tympanic cavity) and the internal ear (labyrinth). The external ear consists of the auricle and the external auditory meatus; the auricle and outer one-third of the external meatus are cartilaginous and are therefore radiographically unimportant.

The **bony part of the external meatus** (Fig. 189) is about three-quarters of an inch long and is directed medially, forward and slightly downward. It ends at the tympanic membrane (ear drum) which lies obliquely and separates the external ear from the middle ear (tympanic cavity). The outer surface of the

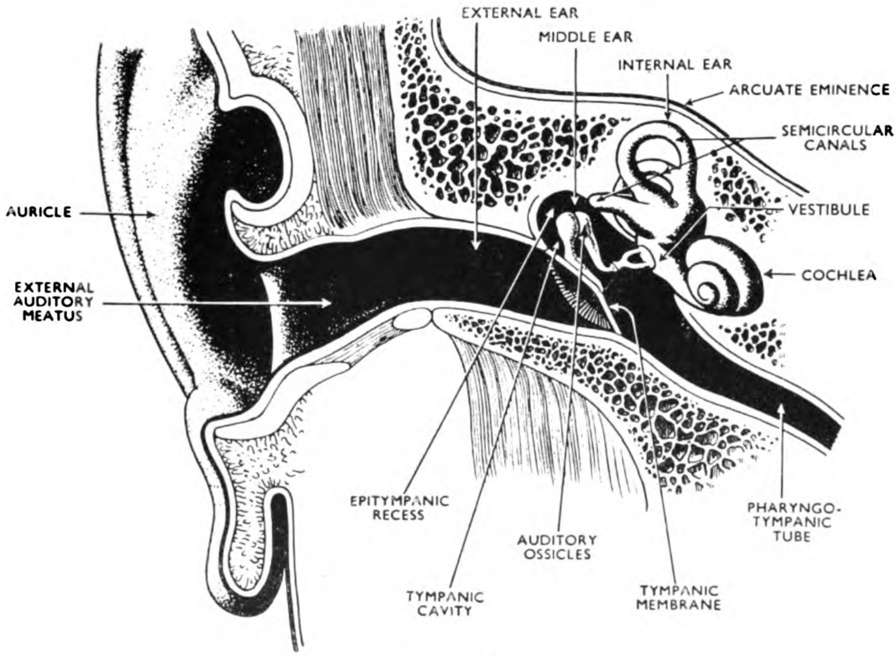


FIG. 189
Diagram showing parts of external, middle and internal ear.

membrane is slightly concave; the inner surface has attached to it part of the malleus, one of the three auditory ossicles situated in the tympanic cavity.

The **middle ear or tympanic cavity** is a small narrow space in the petrous part of the temporal bone between the tympanic membrane and the lateral wall of the internal ear. It is shaped like a match-box, with its long axis parallel to the tympanic membrane, and it contains the three auditory ossicles—the malleus, the incus and the stapes. These ossicles form a chain of very small bones which transmit the vibrations of the tympanic membrane across the tympanic cavity to the internal ear. A part of the cavity lies above the level of the tympanic membrane and is called the epitympanic recess; it contains the head of the malleus and part of the incus. The lateral wall, as

previously stated, is formed chiefly by the tympanic membrane. The medial wall, near its centre, presents a well-marked prominence called the promontory, which is due to the basal turn of the cochlea of the internal ear; above and behind the promontory there is an oval window, the fenestra vestibuli, which is closed by the base (footplate) of the stapes. The roof is formed by a bony plate called the tegmen tympani which separates the tympanic cavity from the temporal lobe of the brain. The floor lies immediately above the jugular fossa. The anterior wall shows the opening of the auditory (pharyngo-tympanic) tube; this connects the pharynx with the middle-ear cavity and allows air pressure on both sides of the tympanic membrane to remain equal. The upper part of the posterior wall presents an opening called the aditus, which leads into the antrum and air cells of the mastoid process.

The **auditory ossicles** (Fig. 190) are all very small bones. The malleus is so called because it resembles a hammer in shape. It is the largest of the

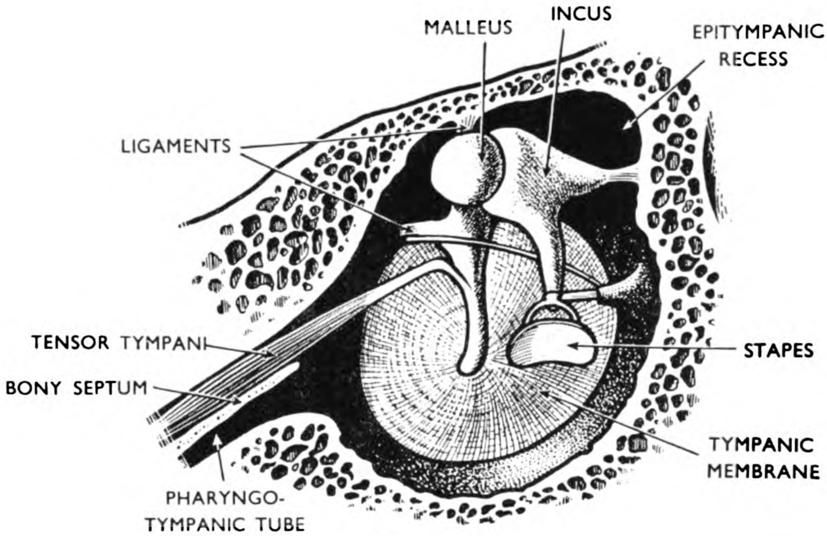


FIG. 190
Diagram showing internal surface of tympanic membrane and auditory ossicles.

ossicles and is about nine millimetres long. It has a head, a neck, a long process called the handle and two smaller processes. The handle is attached to the upper internal surface of the tympanic membrane and the head articulates with the body of the incus. The incus is shaped like an anvil and has a body and two processes, one long and one short; the long process articulates with the stapes, the last in the chain of ossicles. The stapes is so called because it resembles a stirrup; it consists of a small head and neck, and two limbs which hold between their ends an oval footplate or base. The base of the stapes is attached to the margins of the fenestra vestibuli and transmits the vibrations of the tympanic membrane to the fluid (perilymph) of the internal ear.

The **mastoid antrum** is an irregular-shaped air space behind the tympanic cavity; the air cells of the mastoid process develop as buds from it. At birth the middle ear and mastoid antrum are fully formed and of adult size. Development of the mastoid air cells usually begins when the mastoid process forms about the second year and is complete at puberty. It should be noted that the mastoid air cells vary in size and distribution; in some skulls they are absent or only a few are present, while in other skulls they are large and numerous and may extend downward to the tip of the mastoid process and backward around the sigmoid sinus to be closely related to the cerebellum. Sometimes air cells are also present in the petrous part of the temporal bone, around the canal for the carotid artery, and they may extend even to the apex of the petrous temporal; these air cells develop as buds from the anterior part of the tympanic cavity or from the auditory tube. It will therefore be appreciated that infection from the mastoid air cells may spread upward through the roof of the antrum to the temporal lobe of the brain or backward to the sigmoid sinus and beyond this to the cerebellum.

The **internal ear or labyrinth** (Fig. 189) is situated in the petrous part of the temporal bone medial to the tympanic cavity and contains the essential organs of hearing and balance. It consists of a communicating series of membranous sacs and ducts (the membranous labyrinth) enclosed in bony cavities of similar shape (the bony labyrinth); both the membranous and bony labyrinths are filled with a fluid similar to cerebrospinal fluid.

The **bony labyrinth** consists of three parts—the cochlea, the vestibule and the semicircular canals. The bony cochlea is shaped like a snail's shell and consists of a central column, the modiolus, around which a spiral tube winds for two and three-quarter turns. A spiral ledge of bone projects into the cochlea from the modiolus and supports the membranous cochlea. The vestibule is placed between the cochlea in front and the semicircular canals behind. In its lateral wall lies the fenestra vestibuli which is closed by the footplate of the stapes. The semicircular canals are three in number—superior, lateral and posterior. They are arranged at right angles to each other and surround the membranous semicircular ducts. The upper part of the superior semicircular canal lies under the arcuate eminence on the superior surface of the petrous bone.

The organ of hearing (Organ of Corti) lies in the membranous cochlea; it picks up the vibrations in the fluid of the internal ear produced by the movement of the base of the stapes and transmits them along the cochlear part of the auditory nerve to the brain, where they are interpreted as sound. In like manner there are special receptor areas in the walls of the semicircular ducts which are stimulated by the movement of fluid; they transmit these impulses along the vestibular part of the auditory nerve to be interpreted by the brain as balance.

Frontal Bone

The frontal bone consists of a convex **frontal or squamous part** which forms the forehead and two orbital plates which project horizontally backward, forming the greater part of the floor of the anterior cranial fossa and the roofs of the orbits. The portion of the bone which projects downward between the supra-orbital margins is called the **nasal part** (Fig. 191). It has a serrated lower margin which articulates on each side with three bones—the nasal bone, the frontal process of the maxilla and the lacrimal bone in that order from the midline laterally. The nasal spine projects downward from the centre of the nasal part and forms a very small portion of the nasal septum.

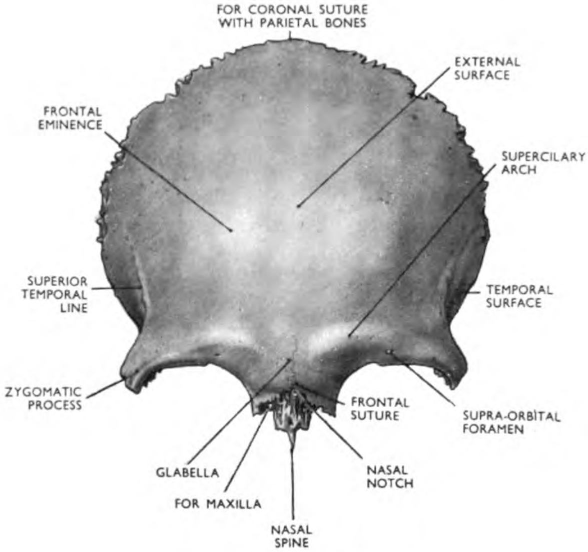


FIG. 191
Frontal bone : anterior aspect.

The **orbital plates** are separated in the midline by the ethmoidal notch (Fig. 192), which is closed in the articulated skull by the cribriform plate of the ethmoid. The lateral margins of the ethmoid notch show a number of small depressions which form the roofs of the ethmoidal air cells. The openings of the frontal sinuses can be seen in the front of the ethmoidal notch on either side of the nasal spine.

The frontal sinuses extend upward and outward between the inner and outer tables of the frontal bone behind the superciliary arches, but may also extend backward into the orbital plates. The inferior surface of each orbital plate is smooth and concave and laterally shows a shallow depression for the lacrimal gland.

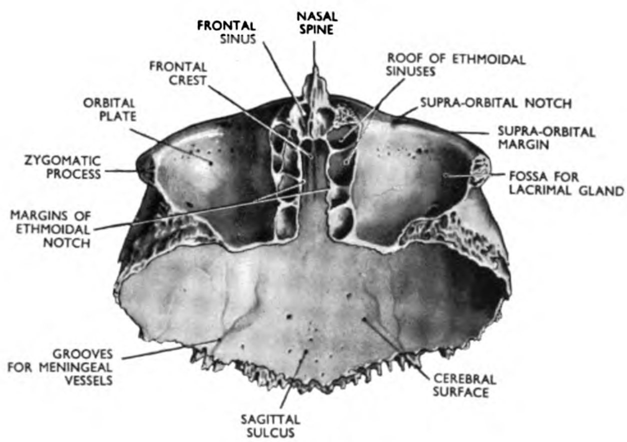


FIG. 192
Frontal bone : inferior aspect.

Parietal Bone

The parietal bone is important because it overlies the main motor and sensory areas of the brain and contains grooves for the anterior and posterior branches of the middle meningeal artery. It is a large quadrilateral-shaped bone which forms the greater part of the vault of the cranium.

Its **external surface** (Fig. 193) is convex and shows two well-marked temporal lines which give attachment to the temporalis muscle and its overlying fascia. Above the temporal lines the bone is covered by the five layers of the

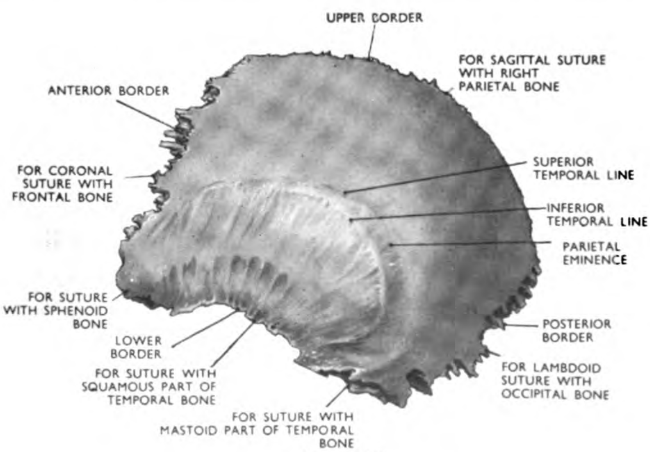


FIG. 193
Parietal bone : external surface.

scalp. Below the lines the bone is protected by the thick temporalis muscle. The prominent convexity on the outer surface is called the parietal eminence and is the site at which ossification commences.

The **internal or cerebral surface** (Fig. 194) is marked by the convolutions of the brain and shows well-marked grooves for the two main branches of the middle meningeal artery, which may be damaged in head injuries. The anterior border of the bone articulates with the frontal bone to form the coronal suture; the posterior border articulates with the occipital bone forming the lambdoid suture, and the upper border articulates with the opposite parietal

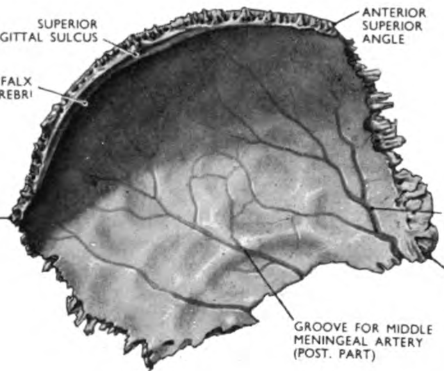


FIG. 194
Parietal bone : internal surface.

bone at the sagittal suture. The lower border articulates from before backward with the sphenoid, the squamous part of the temporal and the mastoid part of the temporal bone. Note also that on the upper border of the internal surface there is a groove for the superior sagittal venous sinus; the fold of dura mater which separates the cerebral hemispheres, the falx cerebri, is attached to the margins of this groove.

Occipital Bone

The occipital bone encloses the foramen magnum and may be divided into three parts—the squamous part is the large curved plate behind the foramen magnum, the lateral or condylar parts are situated on either side, and the basilar part lies in front of the foramen magnum.

The **squamous part** is curved from side to side and from above downward. It narrows to an apex superiorly and is wedged between the two parietal bones with which it articulates at the lambdoid sutures; the lower part of the lateral margin articulates with the mastoid part of the temporal bone. The internal surface (Fig. 196) is concave and is divided into four fossae by the horizontal grooves for the transverse venous sinuses and by a superior and inferior vertical ridge. Note that on the right side of the superior vertical ridge is the groove for the sagittal venous sinus which usually turns into the right transverse sinus, and that where the sinuses meet in the midline there is a bony prominence

called the internal occipital protuberance. The lower vertical ridge is known as the internal occipital crest and gives attachment to the fold of dura mater which separates the cerebellar hemispheres. On the external surface (Fig. 195) the external occipital crest extends upward in the midline from the foramen magnum to the external occipital protuberance which usually lies at a slightly lower level than the internal protuberance. Extending outward on each side from the external protuberance is a curved line, the superior nuchal line, which gives attachment to the superficial muscles of the neck. A second less prominent line may be seen below the superior nuchal line, and is called the inferior nuchal line.

The **lateral or condylar parts** of the occipital bone are placed on either side of the foramen magnum. Each part carries on its under surface an occipital

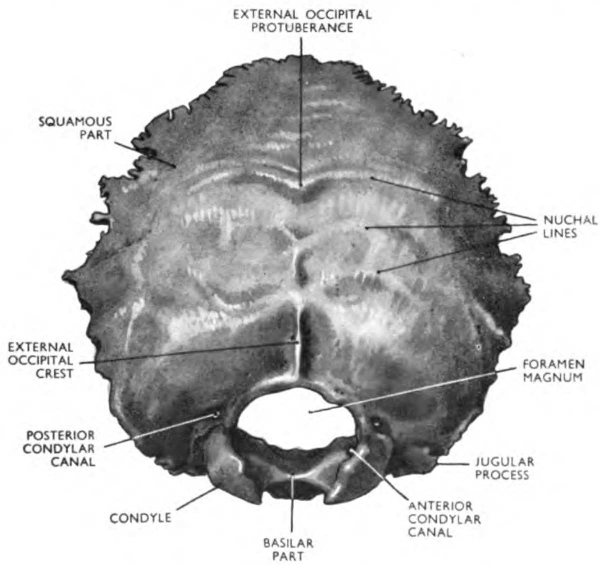


FIG. 195
Occipital bone : external surface.

condyle which articulates with the atlas vertebra (Fig. 195). The condyles are placed obliquely beside the foramen magnum so that their anterior ends are closer together than their posterior ends. Above the condyles the anterior condylar canals pass in a forward and outward direction and transmit the hypoglossal nerves. There may also be posterior condylar canals at the back of the condyles for emerging veins from the cranial cavity. The bone lateral to the condyle is called the jugular process; its cerebral surface is grooved by the end of the sigmoid sinus (Fig. 196) and forms the posterior margin of the jugular foramen. On the cerebral surface of the condylar part there is a bony eminence, the jugular tubercle, which overlies the anterior condylar canal.

The basilar part is the thick oblong section of bone in front of the foramen

magnum. It articulates anteriorly with the body of the sphenoid. Its cerebral surface forms the posterior part of the clivus, and on its inferior surface there

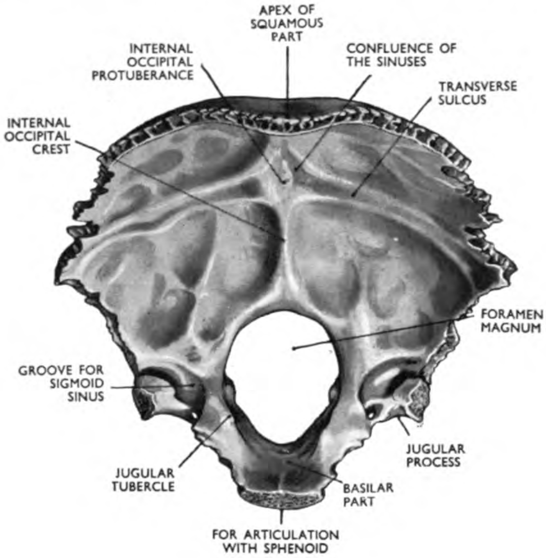


FIG. 196
Occipital bone : internal surface.

is a small elevation called the pharyngeal tubercle to which the pharynx is attached.

Sphenoid Bone

The sphenoid bone may be likened in shape to an aeroplane with cabin, wings and undercarriage (Fig. 198). It consists of a body, two lesser and two greater wings and two pterygoid processes which project downward from the junction of the greater wings and body. Due to its central position in the base of the cranium, the sphenoid articulates with all the cranial bones and also with many of the facial bones, including the maxillae, vomer, zygomatic and palatine bones.

The **body** is cube-shaped and contains the two sphenoidal air cells, separated by a midline septum. The ethmoidal spine at the front of the superior surface (Fig. 197) articulates with the cribriform plate of the ethmoid. On the upper surface between the spine and the optic groove the bone is smooth and is called the jugum sphenoidale. The optic groove extends laterally to become continuous with the optic foramina and is limited posteriorly by the tuberculum sellae, which marks the anterior margin of the sella turcica. The sella turcica comprises the tuberculum sellae, the pituitary fossa and the dorsum sellae, and has already been described. The sides of the body of the sphenoid fuse with the greater wings and in this situation there is a groove, the carotid sulcus, in which the internal carotid artery lies. Behind the dorsum sellae the

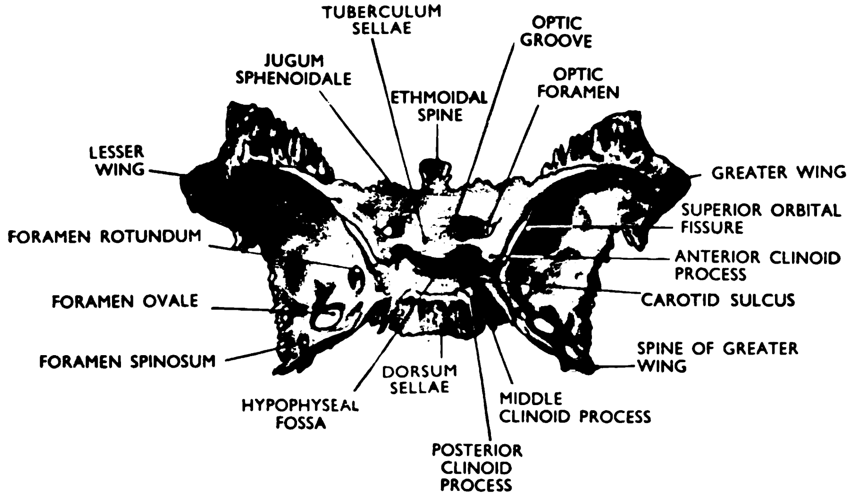


FIG. 197
Sphenoid bone : upper aspect.

sphenoid articulates with the occipital bone. On the anterior surface of the body (Fig. 198) there is a midline ridge, the sphenoidal crest, which is continued on the under surface of the body as the rostrum. The crest articulates

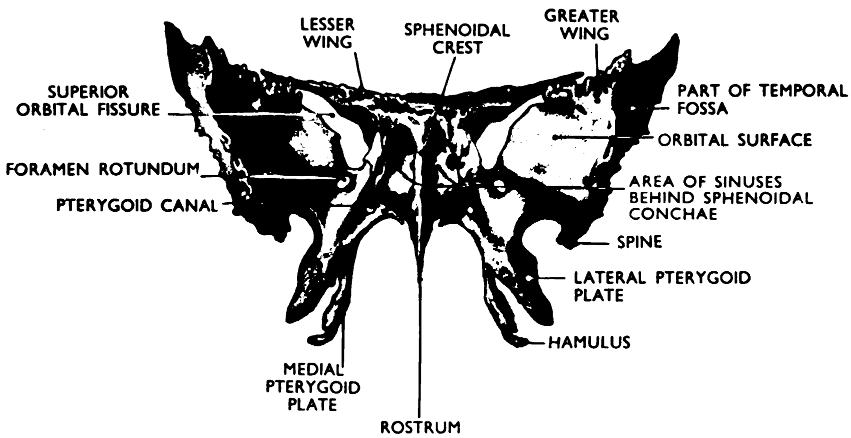


FIG. 198
Sphenoid bone : anterior aspect.

with the perpendicular plate of the ethmoid and the rostrum with the vomer and in this manner helps to support the nasal septum. On either side of the crest the anterior wall of each sinus is formed by a separate bone called the sphenoidal concha, through which the sinus opens into the nasal cavity above the superior nasal concha.

The lesser wings project laterally from the upper anterior part of the body

and form the posterior edge of the anterior cranial fossa. They are thin and triangular in shape, with sharp-pointed outer ends. Each lesser wing is attached to the body by two roots and between these two roots lies the optic foramen. The medial end of each lesser wing projects backward to form the anterior clinoid process.

The **greater wings** extend laterally from the body. The concave superior or cranial surface forms a large part of the middle cranial fossa; the external or temporal surface assists in the formation of the temporal fossa; and the orbital surface, directed forward and medially, forms a considerable part of the lateral wall of the orbit. The upper border of the orbital surface is separated from the lesser wing by the superior orbital fissure, and the lower border from the maxilla by the inferior orbital fissure. Three foramina are present on the upper surface, the foramen rotundum, the foramen ovale and the foramen spinosum in that order from before backward. Note that the foramen lacerum is not an opening in the sphenoid bone but a gap between the apex of the petrous temporal and the greater wing of the sphenoid.

The **pterygoid processes** project downward to form posterior buttresses to the facial bones. Each process consists of a medial and a lateral plate fused together superiorly and separated behind by a fossa. The hamulus at the lower end of the medial plate is often visible on radiographs of the upper teeth beyond the shadow of the alveolar margin.

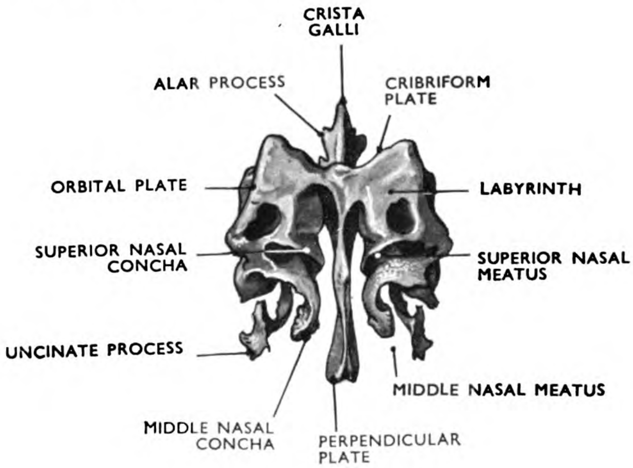


FIG. 199
Ethmoid bone : posterior aspect.

Ethmoid Bone

This is a delicately constructed bone which occupies the upper part of the nasal cavity, lying between the two orbits and in front of the sphenoid. It consists essentially of a perpendicular plate and a horizontal plate from which is suspended the labyrinth of ethmoidal air cells (Fig. 199).

The **perpendicular plate** forms the upper part of the nasal septum and is continued above the horizontal plate as a bony projection called the crista galli.

The **medial part of the horizontal plate** is known as the cribriform plate because of its many perforations for the passage of the olfactory nerves from the olfactory area of the nasal mucous membrane; the cribriform plate forms the median part of the floor of the anterior cranial fossa and lies between the orbital plates of the frontal bone.

The **lateral part of the horizontal plate** suspends the labyrinth of ethmoidal air cells. These cells are closed laterally by a very thin plate of bone called the orbital plate (Fig. 200) which forms part of the medial wall of each orbit. The medial wall of the labyrinth is very irregular and is characterised by the

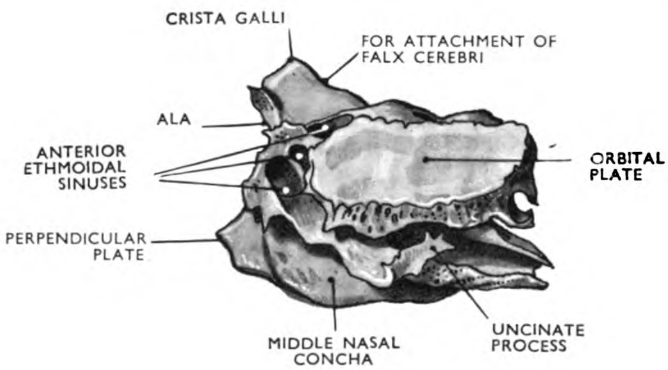


FIG. 200
Ethmoid bone : lateral aspect.

presence of two curved bony projections called the superior and middle nasal conchae. The air cells within the labyrinth are divided into three main groups—anterior, middle and posterior. The posterior ethmoidal cells have a single opening into the superior meatus of the nasal cavity, which is the space overhung by the superior concha. The middle ethmoidal cells form a swelling on the medial wall of the labyrinth called the bulla, and on to which they open; this opening lies in the middle nasal meatus. The anterior ethmoidal cells open into the middle meatus in front of the bulla, and between them and the bulla there is the opening for the frontal sinus. Lastly, from the under surface of the ethmoid labyrinth there is a downward projection called the uncinate process, which forms part of the medial wall of the maxillary sinus; through this process the maxillary sinus opens into the middle meatus.

Vomer

The vomer is a thin plate of bone which forms the postero-inferior part of the nasal septum (Fig. 185). Its upper border divides into two diverging

plates of bone known as alae, which embrace the rostrum on the under surface of the body of the sphenoid (Fig. 183).

Nasal Bones

The nasal bones are two small oblong plates of bone which together form the bridge of the nose (Fig. 181). The lateral border of each bone articulates with the frontal process of the maxilla, and the two bones articulate with each other in the midline. The short superior border articulates with the nasal part of the frontal bone and the lower border gives attachment to the nasal cartilages.

Maxilla

The two maxillae unite to form the greater part of the bony structure of the face (Fig. 177), including the whole of the upper jaw, parts of the orbital and nasal cavities and the anterior two-thirds of the hard palate. Each bone

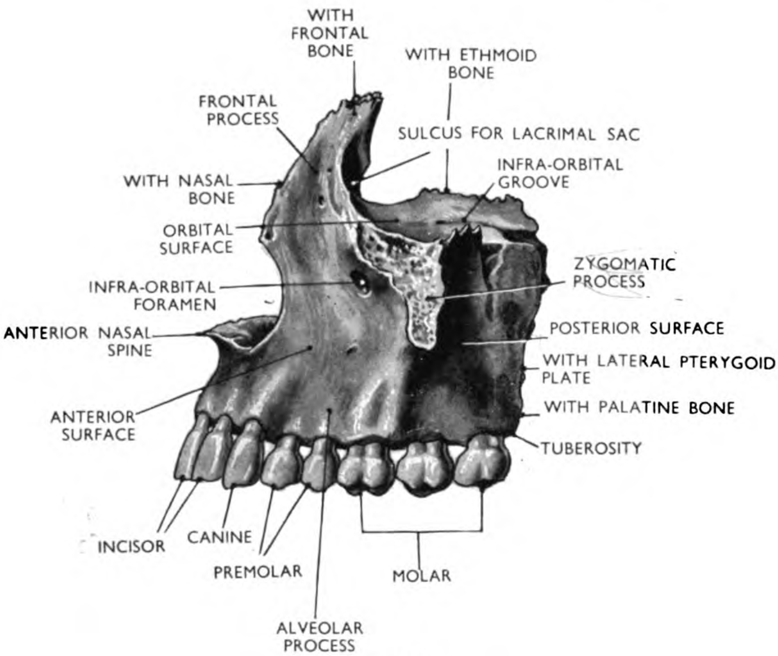


FIG. 201
Maxilla : lateral aspect.

consists of a body and four processes, zygomatic, frontal, alveolar and palatine. The **body** is pyramidal in shape and contains a large cavity called the maxillary sinus. The anterior surface (Fig. 201) looks forward and laterally; it is separated from the superior or orbital surface by the infra-orbital margin, below which lies the infra-orbital foramen; its medial margin forms the nasal notch which ends below in the anterior nasal spine. The lower part of the

anterior surface is marked by a number of ridges corresponding to the roots of the upper teeth; the ridge for the canine tooth is the most prominent. The posterior surface of the body forms the anterior wall of the infratemporal fossa. Beyond the last molar tooth it presents a rounded eminence called the maxillary tuberosity. The superior or orbital surface is triangular in shape and forms the greater part of the floor of the orbit; it is crossed by the infra-orbital groove which passes into the bone to become a canal and emerges at the infra-orbital foramen. It articulates with the lacrimal bone and the orbital plate of the ethmoid. The posterior margin of this surface forms the anterior lip of the inferior orbital fissure. The medial or nasal surface forms a large part of the lateral wall of the nasal cavity (Fig. 186); on its upper part is a large opening, the maxillary hiatus, which leads into the maxillary sinus; in the articulated skull the hiatus is greatly reduced in size by the lacrimal bone in front, the ethmoid above and the inferior nasal concha below. In front of the maxillary hiatus lies the lacrimal groove which is converted into the naso-lacrimal canal by the lacrimal bone and the inferior nasal concha; this canal opens into the inferior nasal meatus and transmits the naso-lacrimal duct. The inferior nasal concha articulates with an oblique ridge, the conchal crest, on the anterior part of the nasal surface.

The **zygomatic process** is a roughened triangular area on the lateral aspect of the body which articulates with the zygomatic bone.

The **frontal process** projects upward and slightly backward. Its anterior border articulates with the nasal bone, the posterior border with the lacrimal bone and the superior border with the nasal part of the frontal bone.

The **palatine process** projects horizontally from the lower part of the nasal surface and forms, with its neighbour, the anterior two-thirds of the hard palate (Fig. 183). In the midline the two palatal processes fuse to form the nasal crest which receives the lower border of the vomer. The free anterior end of the nasal crest forms the anterior nasal spine. On the inferior surface, behind the incisor teeth, is the incisive foramen which transmits small vessels and nerves from the nasal cavity to the roof of the mouth.

The **alveolar process** projects downward from the body of the maxilla to form, with the process of the opposite side, the upper dental arch which provides sockets for the teeth of the upper jaw. It is broader posteriorly to accommodate the three roots of each molar tooth. Each tooth socket is lined with a thin layer of compact bone called the lamina dura and between it and the root of the tooth is the dental periosteum or periodontal membrane.

The **maxillary sinus** is a large pyramidal-shaped cavity in the body of the maxilla. Its apex lies near the zygomatic process and its base is formed by the lateral wall of the nasal cavity. In the articulated skull the opening of the sinus lies near its roof so that fluid levels are not uncommon if the sinus becomes infected.

Palatine Bone

The palatine bone is a small bone shaped like the letter L. It consists of a horizontal and a vertical plate.

The **horizontal plate** forms the posterior quarter of the hard palate and can be seen on the under surface of the skull (Fig. 183).

The **vertical plate** is a thin plate of bone in the posterior part of the lateral wall of the nasal cavity (Fig. 186); it lies against the maxilla and articulates posteriorly with the medial pterygoid plate of the sphenoid bone. Two bony processes project upward from its upper border enclosing a notch through which pass vessels and nerves to the mucous membrane of the nasal cavity. The medial surface of the vertical plate shows a horizontal ridge, the conchal crest, to which the inferior nasal concha is attached.

The **tubercle or pyramidal process** is a small process which projects backward from the junction of the horizontal and vertical plates and fits in between the lower ends of the pterygoid plates of the sphenoid bone.

Lacrimal Bone

The lacrimal bone is a very small thin bone situated in the medial wall of the orbit between the frontal process of the maxilla and the ethmoid bone (Fig. 181). The lacrimal sac lies in a deep groove which the lacrimal bone forms with the frontal process of the maxilla.

Zygomatic Bone

This is a small quadrangular bone situated in the upper part of the side of the face, forming the prominence of the cheek. It consists of a body and four processes, maxillary, frontal, temporal and orbital (Figs. 181 and 182).

The outer surface of the **body** is slightly convex and shows two foramina for the passage of nerves and vessels from the orbit to the soft tissues of the cheek. The **maxillary process** articulates medially with the maxilla ; the **frontal process** projects upward to articulate with the zygomatic process of the frontal bone ; the **temporal process** is directed backward to join the zygomatic process of the temporal bone and so complete the zygomatic arch ; the **orbital process** forms part of the lateral and inferior walls of the orbit and articulates with the greater wing of the sphenoid and the orbital surface of the maxilla. Because of its prominent position in the face, the zygomatic bone is often fractured.

Mandible

The mandible or lower jaw forms the skeleton of the lower part of the face. It consists of a horseshoe-shaped body and two vertical rami (Figs. 202 and 203). At the upper end of each ramus are two projections, the coronoid process and the condylar process; they are separated by a gap called the mandibular notch,

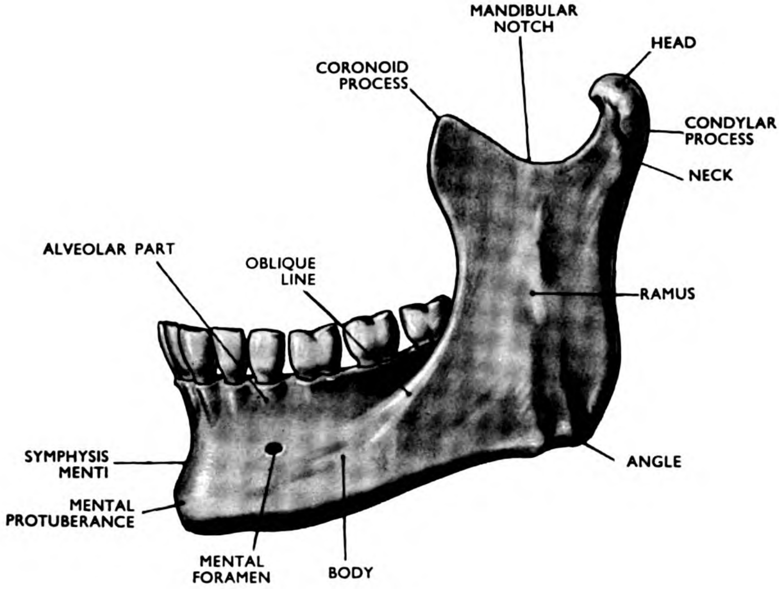


FIG. 202
Mandible : external surface of left side.

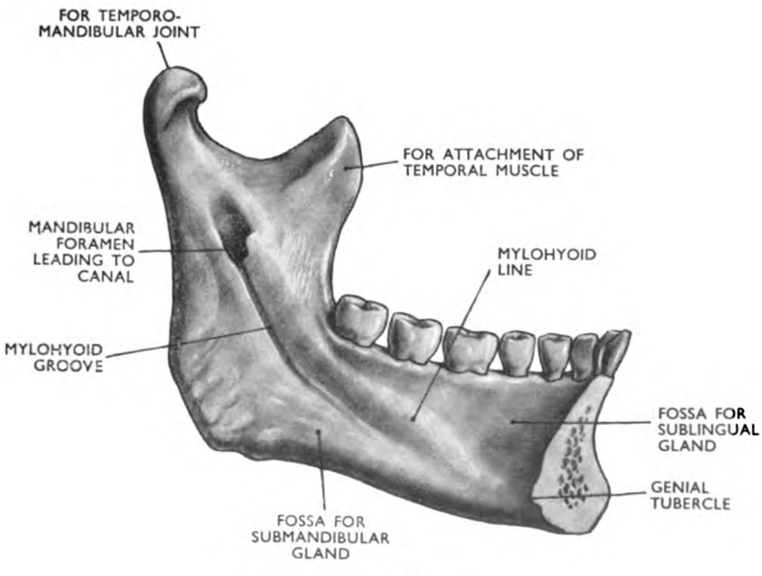


FIG. 203
Mandible : internal surface of the left side.

through which pass nerves and vessels to the overlying masseter muscle. A median ridge on the outer surface of the **body** is called the symphysis menti and marks the line of fusion of the two halves of the body which takes place in the second year. The upper margin of the body is called the alveolar process and contains the sockets for the roots of the lower teeth. Below the premolar teeth lies the mental foramen which transmits a nerve to supply the overlying skin. The oblique line gives attachment to the muscles which depress the lower lip and hold the food between the teeth during mastication. The inner surface of the body also shows special features. Note the mylohyoid line ; it gives attachment to the mylohyoid muscle which forms the greater part of the floor of the mouth. Above this line is the fossa for the sublingual salivary gland and below the fossa for the submandibular gland. The genial tubercle gives attachment to one of the important muscles of the tongue.

The **ramus,** on its outer surface, gives attachment to the masseter muscle, an important muscle of mastication. The **angle** lies at the junction of the inferior and posterior borders of the ramus and is a valuable landmark. On the inner surface of the ramus is the mandibular foramen, the opening of the mandibular canal, which transmits the nerve and blood supply to the lower teeth. The mylohyoid groove is formed by the mylohyoid nerve which descends in this position. The **coronoid process** gives attachment to the temporal muscle. The **condylar process** consists of an expanded head and a neck ; the head forms the temporo-mandibular joint with the mandibular fossa of the temporal bone. The head is widened from side to side and is separated from the mandibular fossa by a fibrocartilaginous disc. When the mouth is shut the head and disc lie in the mandibular fossa, but on opening the mouth the head moves forward on to the articular tubercle.

Hyoid Bone

The hyoid bone is of little importance radiographically, but it is briefly described, since it is commonly seen in radiographs. It lies in the front part of the neck above the thyroid cartilage and below the floor of the mouth. It consists of a body and two greater and two lesser cornua (Fig. 204). It gives attachment above to some of the muscles of the floor of the mouth and extrinsic muscles of the tongue, and below to the infrahyoid or strap muscles of the neck which depress the hyoid after it has been raised during swallowing. It also gives attachment to the middle constrictor muscle of the pharynx.

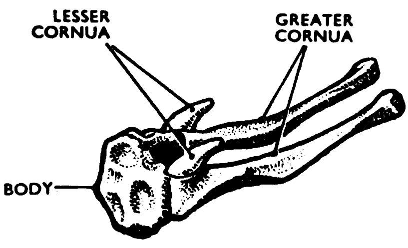


FIG. 204
Hyoid bone: left supero-lateral aspect.

RADIOGRAPHY OF THE SKULL

In the radiographic examination of the skull various reference lines between surface markings are used to ensure correct positioning of the head. The lines most frequently employed are :—

1. The line of the **median plane** which divides the head into a right and a left half.
2. The **interorbital (interpupillary) line** which passes between the pupils of the eyes when the subject is looking straight ahead.
3. The **orbito-meatal line or radiographic base line** which runs from the external auditory meatus to the outer canthus or lateral angle of the eye. Adjustment of the angulation of this line relative to the film is often made to ensure the projection of the petrous shadow to a position where it will not obscure other structures under examination.

Reid's base line, used when viewing the skull in orthodontics, differs from the radiographic base line by 10°, as it uses the lower border of the orbit in place of the outer canthus of the eyelids.

For the purposes of description, it is convenient to divide the skull into the following radiographic areas :—

1. Cranial Bones.
2. Temporal Bone.
3. Facial Bones.
4. Paranasal Sinuses.
5. Mandible and Temporo-mandibular Joint.
6. Teeth.

A great many radiographic views for each area have been described, but only those most commonly employed will be given.

RADIOGRAPHIC APPEARANCES OF THE CRANIAL BONES

The four following radiographic views are commonly employed to demonstrate the main bony features of the cranium :—

1. Lateral radiograph.
2. Occipito-frontal radiograph.
3. 30° Fronto-occipital radiograph (Towne's projection).
4. Submento-vertical radiograph.

Additional view—modified submento-vertical radiograph for the jugular foramina.

Cranial Bones: Lateral Radiographs (Figs. 205 and 206)

This radiograph is taken with the head positioned so as to bring the median plane parallel, and the interorbital line at right angles, to the film. It is not possible to demonstrate both the cranial and the facial bones on a single lateral radiograph, owing to the marked difference in bone density between these two areas. The radiographs shown were taken to show the cranial bones and

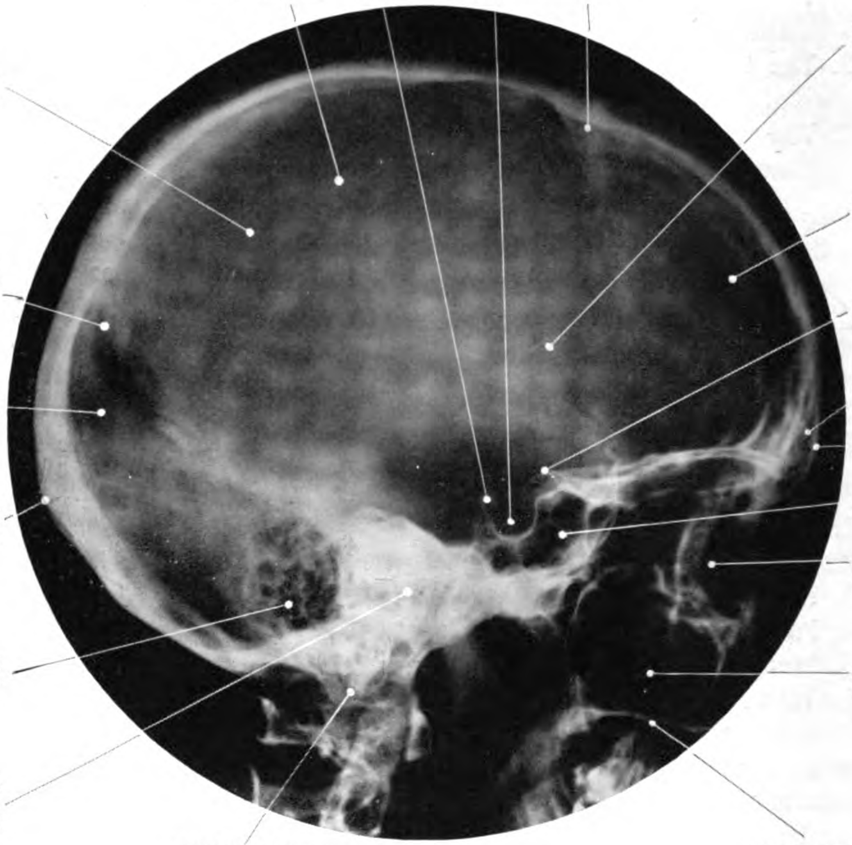


FIG. 205
Cranial bones : lateral radiograph.

have consequently resulted in overexposure of the facial bones, although some bony features may still be recognised.

The main features of this radiograph correspond to those seen in the sagittal section of the skull (Fig. 185). Note that the general plane of the base of the cranium is inclined at a slight angle to the horizontal and that the facial bones are suspended from the front of the cranial base. The internal surface of the base is naturally subdivided into three cranial fossae, and these are visible as a series of steps at successively lower levels from front to back.

The sella turcica is the prominent central feature of the base and it is formed by the upper surface of the body of the sphenoid bone. The pituitary fossa has a regular half-round contour and is bounded posteriorly by the dorsum

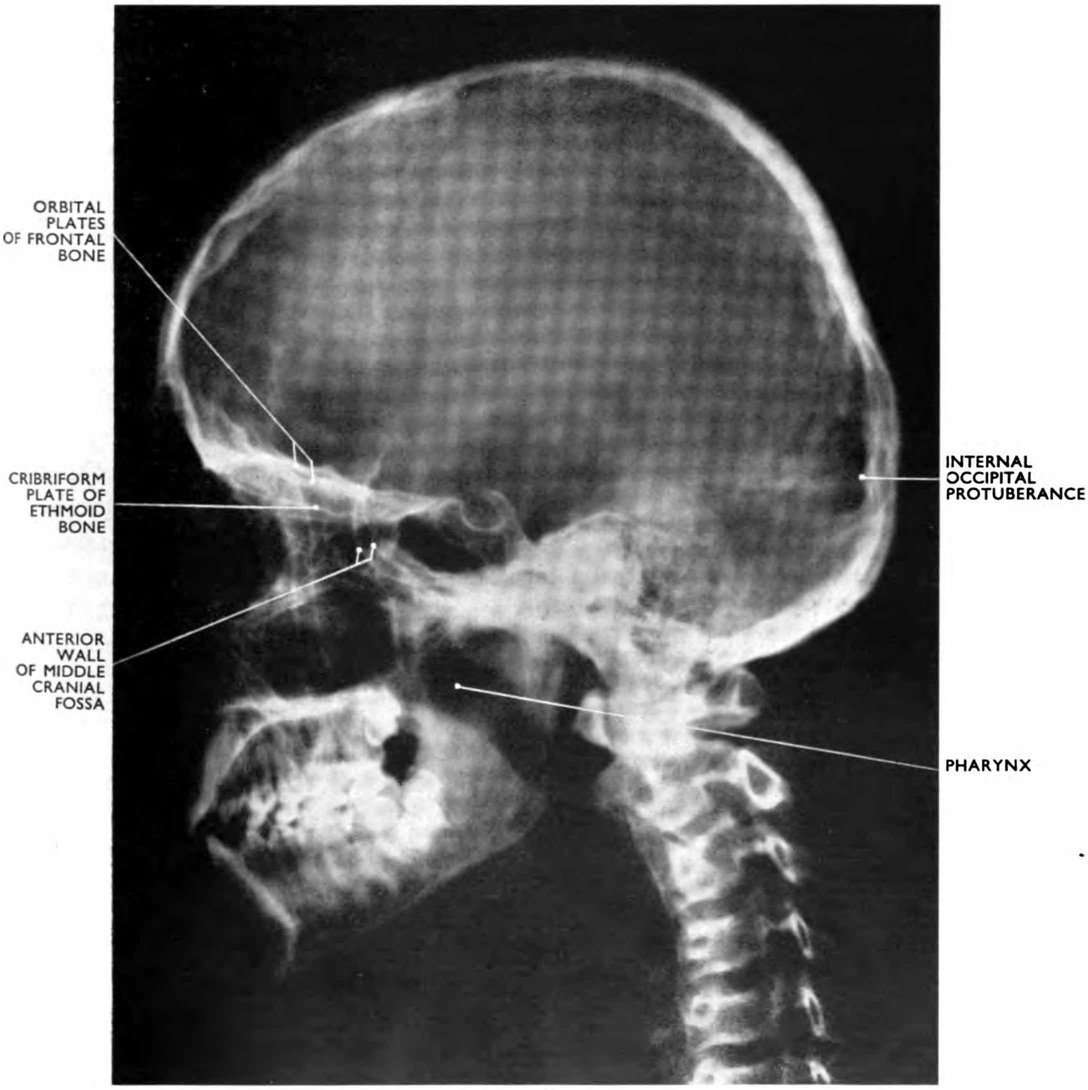


FIG. 206
Cranial bones : lateral radiograph.

sellae whose upper margin slightly overhangs the fossa. The tuberculum sellae forms the anterior margin of the sella and is seen as a prominent ridge in front of the fossa ; the short inclined surface in front of the tuberculum is the optic groove. The anterior clinoid processes are almost superimposed on each other and appear to overhang the sella, but are, in fact, situated a

short distance lateral to it. The sphenoidal sinuses are superimposed on each other and are visible as a transradiant area in the body of the sphenoid below and in front of the sella; if well developed, as in these patients, they are separated from the pituitary fossa only by a thin layer of bone. Extending forward from the anterior clinoid processes two parallel lines of denser bone mark the floor of the anterior cranial fossa (Fig. 206); they are cast by the orbital plates of the frontal bone anteriorly and by the lesser wings of the sphenoid posteriorly. A third and less dense line of bone is visible below these two lines; the middle portion of this third line is cast by the cribriform plate of the ethmoid, which is placed at a slightly lower level to the orbital plates of the frontal bone. The frontal sinuses lie between the inner and outer tables of the frontal bone above the root of the nose and are almost obscured by superimposed bone in Figure 205. The lateral parts of the middle cranial fossa are seen in profile as two almost superimposed lines of denser bone which extend downward and backward from the level of the anterior fossa in front of the anterior clinoid processes (Fig. 206). The upper part of each line is cast by the posterior edge of the lesser wing of the sphenoid and the lower part by the greater wing; posteriorly these shadows are continuous with the upper surfaces of the petrous temporal bones. It will be appreciated from these radiographs that the lateral parts of the middle fossa are considerably wider than the raised median part which forms the sella turcica. The petrous temporal bones are superimposed to produce a very dense triangular shadow in which the structures of the middle and internal ear cannot be identified; the temporomandibular joint is also obscured. Below the petrous shadows the outline of one mastoid process is visible and posteriorly some of the mastoid air cells can be seen as bubble-like transradiancies (Fig. 205).

The anterior wall of the posterior cranial fossa is formed in the midline by the dorsum sellae, the body of the sphenoid and the basilar part of the occipital bone. This wall slopes sharply down to the foramen magnum; the upper part is visible above the petrous temporal bones but the lower part is obscured. The cartilaginous plate between the body of the sphenoid and the basilar part of the occipital bone may be seen in radiographs of subjects under the age of 25 years, but the two bones have fused in these skulls. The lateral parts of the anterior wall of the posterior fossa are formed by the posterior surfaces of the petrous temporal bones, but as they incline obliquely inward toward the midline no clear outline is visible on the lateral radiograph. Behind the petrous shadows the occipital bone forms the greater part of the posterior fossa; the internal occipital protuberance, which marks its posterior limit, is visible as a small prominence on the internal surface of the bone at the level of the external protuberance. The bone is thick at the protuberances but becomes thinner as it curves forward to the foramen magnum which is overshadowed by the petrous temporal bones.

In the vault of the skull, the coronal and lambdoid sutures are faintly

visible. The groove for the middle meningeal artery is seen behind the lower end of the coronal suture; above it divides into an anterior branch which extends upward behind the coronal suture to the vertex of the cranium, and a posterior branch which is directed upward and backward across the parietal bone (Fig. 205). The irregular stellate shadows of the diploic vessels can be seen in the parietal bone. Unless a long-distance technique has been used to take this radiographic view, it is usual to see clearly only the vascular channels on the side of the skull nearest the film.

Whilst the outer surface of the frontal bone is smooth, the internal surface shows a number of shallow indentations for the convolutions of the brain; such convolutional markings are occasionally seen in normal adult skulls, but if well developed and extensive they may be of pathological significance. Below the anterior part of the base of the skull it is possible to identify the hard palate, the maxillary sinuses and the air-filled pharynx (Fig. 206).

Cranial Bones: Occipito-frontal Radiograph (Fig. 207)

For this radiograph the X-ray beam is directed in a postero-anterior direction and the head is so positioned that the median plane and the radiographic base line are at right angles to the film. A low centring point at the nape of the neck results in the passage of the centre ray through the general plane of the base of the cranium, and in the subsequent superimposition of the petrous shadows on to the orbits.

Above the base of the cranium the frontal and occipital bones are superimposed. The internal occipital crest is seen as a dense midline shadow, often slightly deviated to one side at its junction with the transverse sulci which may also be faintly visible. The two parietal bones are seen in profile and the parietal eminence forms the prominent convexity on the outer surface of each bone. The coronal and lambdoid sutures are almost superimposed and the sagittal suture is seen nearly end on at the vertex of the skull between the parietal bones.

The petrous temporal bones form the densest part of the base of the cranium and in this radiographic view they extend medially and slightly downward toward the midline across the upper parts of the orbits, although the supra-orbital margins may still be identified. It is sometimes possible in slightly overexposed films to identify some of the structures of the internal ear and some of the mastoid air cells may also be visible near the side wall of the cranium. The frontal sinuses, foreshortened in this view, are seen on either side of the midline over the medial parts of the supra-orbital margins; the bony septum which separates the two sinuses is often deviated to one side as in this radiograph. The ethmoidal sinuses of each side are almost end on to the centre ray and combine to produce a small transradiant area medial to the medial wall of the orbit and below the frontal sinus. The outline of the pear-shaped nasal cavity, wide below and narrow above, can be easily identified in spite of the superimposed cervical vertebrae. It will be remembered that the

upper part of the nasal septum is formed by the perpendicular plate of the ethmoid and the lower and posterior part by the vomer. The middle and inferior nasal conchae are visible as faint rounded shadows on the lateral walls of the nasal cavity. The maxillary sinus is seen as a transradiant triangular

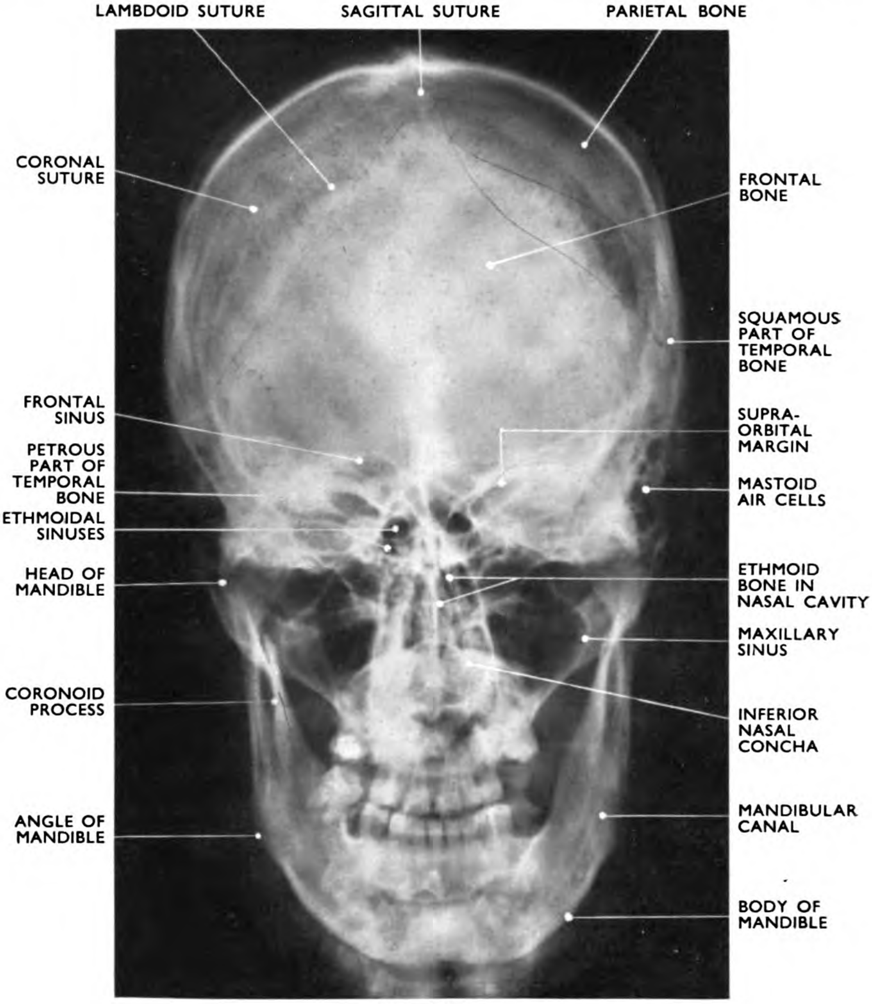


FIG. 207
Cranial bones : occipito-frontal radiograph.

area in the body of the maxilla, lateral to the nasal cavity. The upper jaw is enclosed by the horseshoe-shaped shadow of the mandible. The coronoid process is visible as a pointed shadow of dense bone superimposed on the medial margin of the ramus of the mandible. The ramus is flattened from side to side but is seen to widen above to support the transversely elongated head. The temporo-mandibular joint is completely obscured in this view by the dense petrous shadow.

Cranial Bones: 30° Fronto-occipital (Towne's) Radiograph (Figs. 208 and 209)

This radiograph is taken to demonstrate the posterior part of the cranium, in particular the occipital and petrous temporal bones. The back of the head is placed against the film, with the median plane and base line at right angles

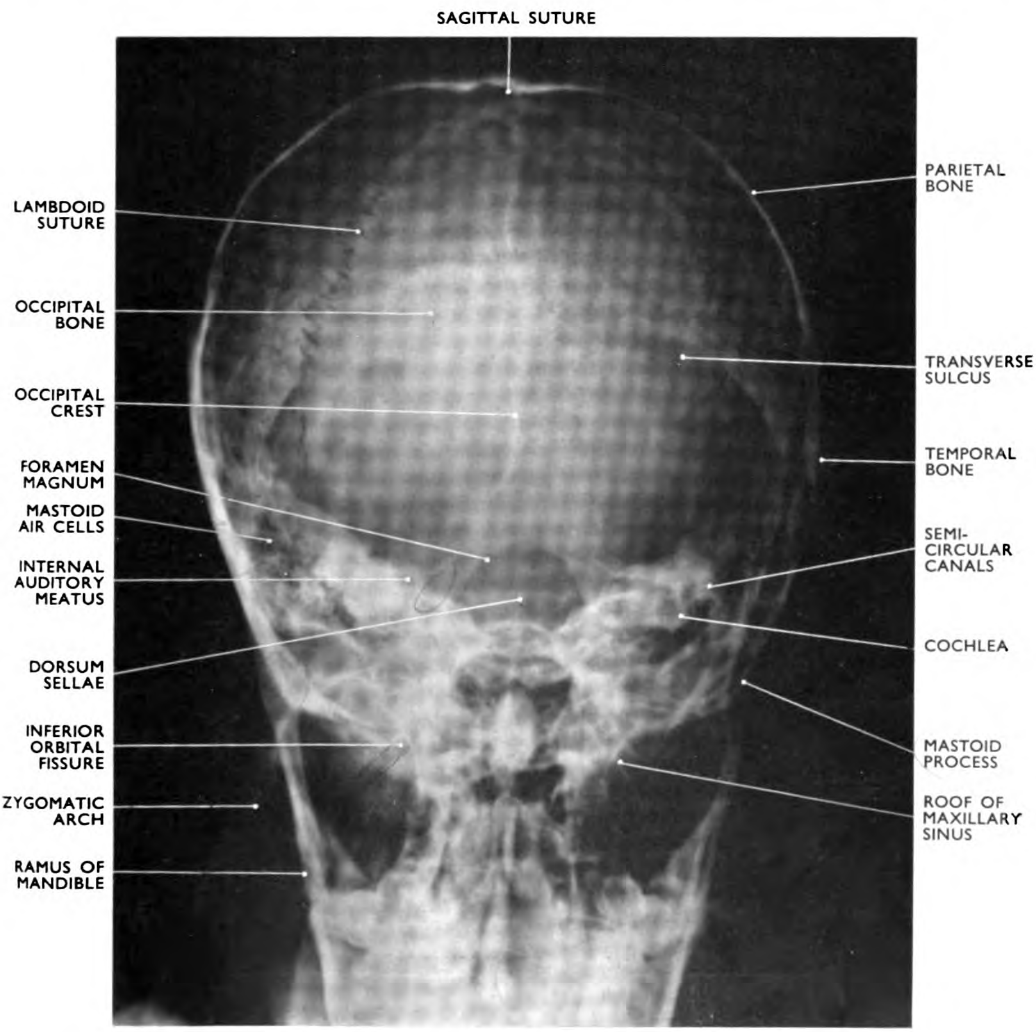


FIG. 208
Cranial bones : 30° fronto-occipital radiograph.

to it ; the X-ray tube is directed downward with 30° angulation toward the feet and is centred to the foramen magnum. This projection throws the shadow of the greater part of the occipital bone above the temporal bones.

In the centre of the radiograph the posterior margin of the foramen magnum is clearly visible. The foreshortened shadow of the dorsum sellae is projected

on to the foramen magnum; its upper margin is flat and the posterior clinoid processes form the prominent corners. A short curved line below the dorsum sellae is cast by the posterior arch of the atlas vertebra. The dense mass of the petrous temporal bone extends outward from the side of the foramen

FIG. 209
Skull: dry bone. 30° fronto-occipital radiograph.

magnum; it is triangular in shape with the apex directed medially. The superior border (petrous ridge) is well defined and slightly irregular. The internal auditory meatus is seen as a channel entering the bone obliquely; lateral to it, the small prominence on the superior border is caused by the arcuate eminence, beneath which the superior semicircular canal is visible as a small semicircular transradiancy. It is often possible on a well-exposed radiograph to see the small transradiant shadow of the cochlea below the

superior semicircular canal; the mastoid antrum lies on its lateral side. The lateral part of the temporal bone inside the cranial wall is marked by numerous air-filled mastoid air cells, which in this particular skull are well developed. A curved line of denser bone, concave downward, below the mastoid cells is cast by part of the roof of the mandibular fossa and the transversely widened head of the mandible is also visible.

The whole of the squamous part of the occipital bone is visible above the foramen magnum and petrous ridges. The centre of this bone shows an area of increased bone density, due to the superimposition of the internal and external occipital protuberances, and it marks the site of confluence of the large venous sinuses. Horizontal and vertical ridges of increased bone density radiate out from this point and divide the squamous part of the bone into four fossae; the two upper fossae lodge the occipital lobes of the brain and the two lower fossae the cerebellar hemispheres. The lower part of the vertical shadow extends almost to the foramen magnum and is due to the internal occipital crest, whilst the upper part is cast by the sagittal sulcus; this sulcus lodges the sagittal sinus and may be seen in profile at the top of the cranial vault.

The horizontal shadows are cast by the transverse sulci and the transverse sinuses lie between their two parallel margins. The transverse sulci curve forward to the mastoid region where they descend on the posterior surface of the temporal bone to become the sigmoid sulci; in this position they are obscured by the mastoid air cells. The right transverse sulcus is frequently larger and situated at a slightly higher level than the left sulcus. Usually the medial end of the right transverse sulcus curves upward to become continuous with the sagittal sulcus, whilst the left sulcus curves downward alongside the internal occipital crest but is visible only for a short distance.

From the apex of the occipital bone the lambdoid sutures extend downward and outward to separate the occipital from the parietal bones. Above the mastoid area this suture divides into two, where the posterior angle of the mastoid part of the temporal bone is wedged in between the occipital and parietal bones. The medial of these two sutures, the occipito-mastoid suture, extends downward behind the petrous ridge; the outer or parieto-mastoid suture is lost after a short distance in the shadow of the side wall of the cranium. Below the foramen magnum and between the apices of the petrous bones is the well-defined central transradiancy of the sphenoidal sinuses. The inferior orbital fissure is visible as a long narrow channel extending forward and outward from the shadow of the sphenoidal sinuses.

The anterior part of the cranial vault is superimposed on the occipital bone but owing to its distance from the film it is ill defined, although the anterior part of the sagittal suture may be identified. The shadows of the facial bones are projected on to the lower part of the radiograph and are superimposed on to the cervical vertebrae; these appearances are too distorted to be easily interpreted. The zygomatic arch is faintly visible lateral to the ramus of the

mandible but it is overexposed on this radiograph which is designed to show the dense bone structures of the cranial base; a radiograph of a dry skull (Fig. 209) shows its position clearly.

Cranial Bones: Submento-vertical Radiograph (Figs. 210 and 211)

This radiographic view of the base of the cranium is taken with the patient's head fully extended so that the top of the head rests against the film; the base

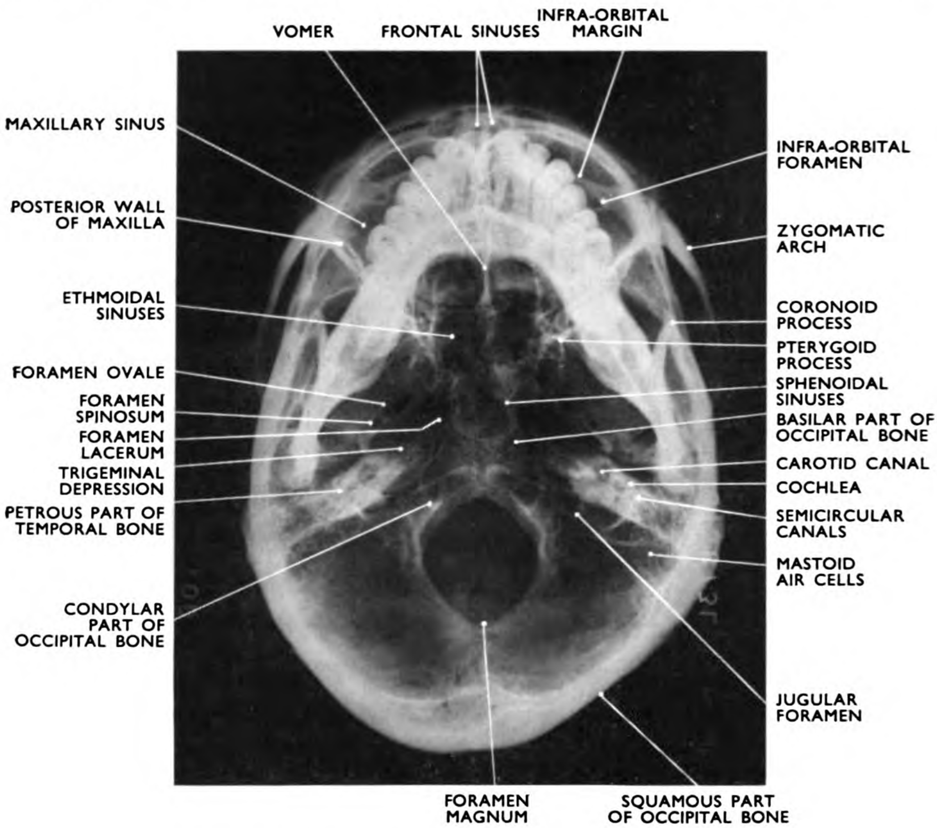


FIG. 210
Skull : dry bone. Submento-vertical radiograph.

line is almost parallel to the film and the centre ray is directed at a point midway between the angles of the mandible.

Although this radiograph is primarily taken to demonstrate the main features of the base of the cranium, it also demonstrates some features of the mandible and facial bones. It is a difficult radiograph to analyse and it will be easier for the student to identify first the main features on a radiograph of a dry skull taken in a similar position (Fig. 210) and in which bone detail is not obscured by soft tissue shadowing.

In Figure 210 the body of the mandible is seen as a dense horseshoe-shaped shadow superimposed on the anterior part of the base of the cranium. In

front of the mandible the shadows of the upper and lower teeth are seen very obliquely and overlap to the extent that detail of their structure is lost. The ramus of the mandible appears as a thinner plate of bone behind the thick body. It is end on to the X rays and partly overshadows the head of the

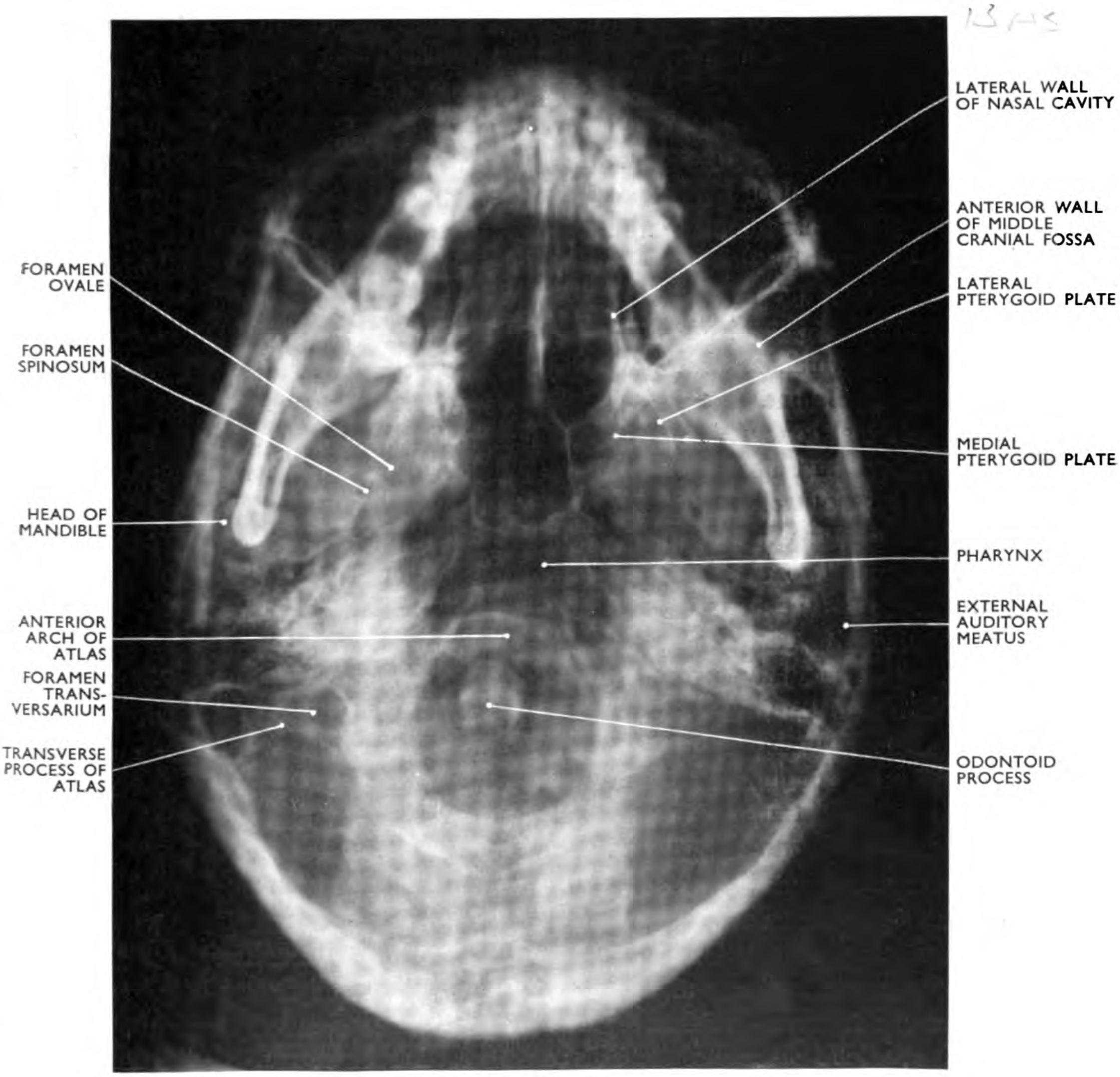


FIG. 211
Cranial bones : submento-vertical radiograph.

mandible, although the anterior margin of the temporo-mandibular joint is visible as a small arched transradiancy in front of the head. In front of the incisor teeth the frontal sinuses are seen in profile as well-defined areas. The infra-orbital margins extend laterally from the level of the canine teeth, and the infra-orbital foramina are also visible. In the midline behind the shadow of

the body of the mandible the posterior end of the nasal septum, formed by the vomer, is visible. A well-defined line of denser bone extends obliquely inward and backward from the anterior part of the base of the cranium to cross the shadow of the mandible near the last molar tooth. It is mainly cast by the posterior surface of the maxilla and ends medial to the shadow of the mandible in a confused area of bone markings; close inspection of this area will reveal the shadows of the medial and lateral plates of the pterygoid process of the sphenoid. Extending forward from the pterygoid process is a thin sharp line cast by the posterior part of the lateral wall of the nasal cavity. The triangular area enclosed by the infra-orbital margin, the posterior surface of the maxilla and the lateral wall of the nasal cavity is formed by the body of the maxilla and contains the transradiant maxillary sinus; in this radiograph part of the sinus is overshadowed by the mandible. The space between the pterygoid processes corresponds to the posterior openings of the nasal cavity and immediately behind are the sphenoidal sinuses contained within the body of the sphenoid. The septum which separates the sinuses cannot be identified clearly in this radiograph. Behind the posterior margins of the sinuses is the basilar part of the occipital bone which extends to the anterior lip of the foramen magnum; the condylar part lies on the antero-lateral margins of the foramen but the condyles are not well outlined. The foramen ovale and the foramen spinosum lie in the greater wing of the sphenoid behind the lateral pterygoid plate, and are visible as two transradiancies, the one oval and the other round. The petrous part of the temporal bone is seen as a well-marked pyramidal area of dense bone. Its base lies near the side of the cranium and its apex is directed forward and medially to end at the foramen lacerum, situated in this radiograph between the foramen ovale and the sphenoidal sinuses. A well-marked transradiant rounded area in the petrous bone behind the foramen spinosum is cast by the opening for the carotid canal, and postero-lateral to this opening are several small transradiancies due to the cavities of the internal ear.

In the submento-vertical radiograph of the living subject (Fig. 211) the shadows of the soft tissues of the base of the skull and the upper part of the cervical spine are superimposed on the appearances seen in Figure 210. The foramen magnum and much of the occipital bone are obscured by the cervical spine; the anterior arch of the atlas vertebra is superimposed on the anterior part of the foramen and immediately behind can be seen the conical shadow of the odontoid process of the axis vertebra. The shadow of the lateral mass of the atlas is superimposed on the occipital condyles and bony detail is lost, but the transverse process and the foramen transversarium can be identified behind the petrous shadow. In the midline between the mandible and the anterior arch of the atlas is a narrow area of transradiancy due to the air-filled nasal cavities and pharynx. The external auditory meatus is also visible as a relatively transradiant shadow behind the head of the mandible, directed inward and slightly forward.

The student may be asked to draw a diagram of the lateral, occipito-frontal,

30° fronto-occipital or submento-vertical radiographs; in a series of diagrams, Figure 212, A to D, a simple method is given. Note particularly the position of the petrous and mastoid parts of the temporal bone in these projections as indicated by the shaded areas.

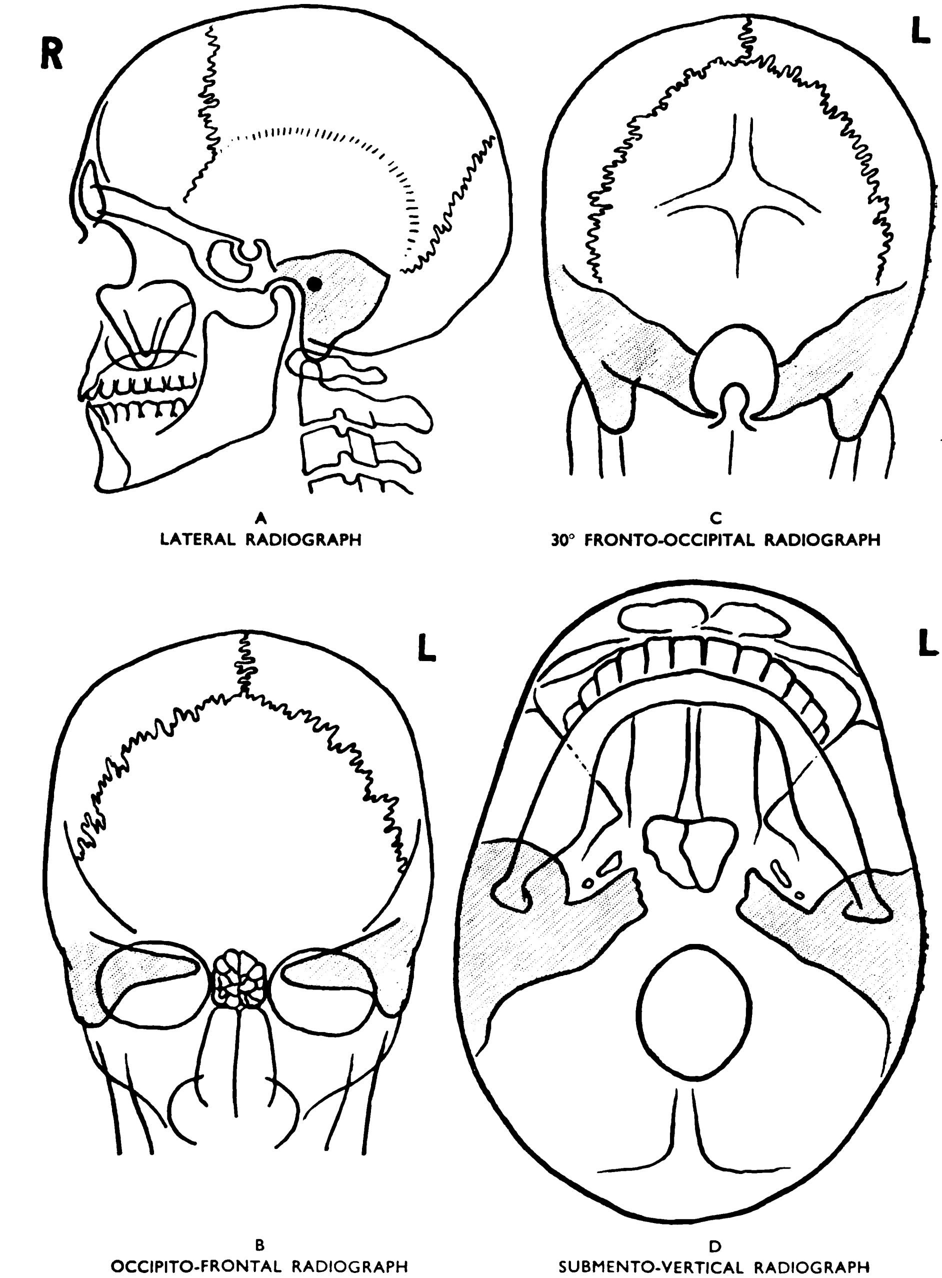


FIG. 212
Series of diagrams of general radiographs of skull.

Cranial Bones: Modified Submento-vertical Radiograph for Jugular Foramen (Fig. 213)

The jugular foramina are difficult to see in a submento-vertical radiograph as they open downward and forward and are therefore oblique to the rays; they are also partly obscured by the shadows of the transverse processes of the atlas vertebra. They may, however, be clearly seen if the radiograph is taken with the head positioned as for the submento-vertical view but with the

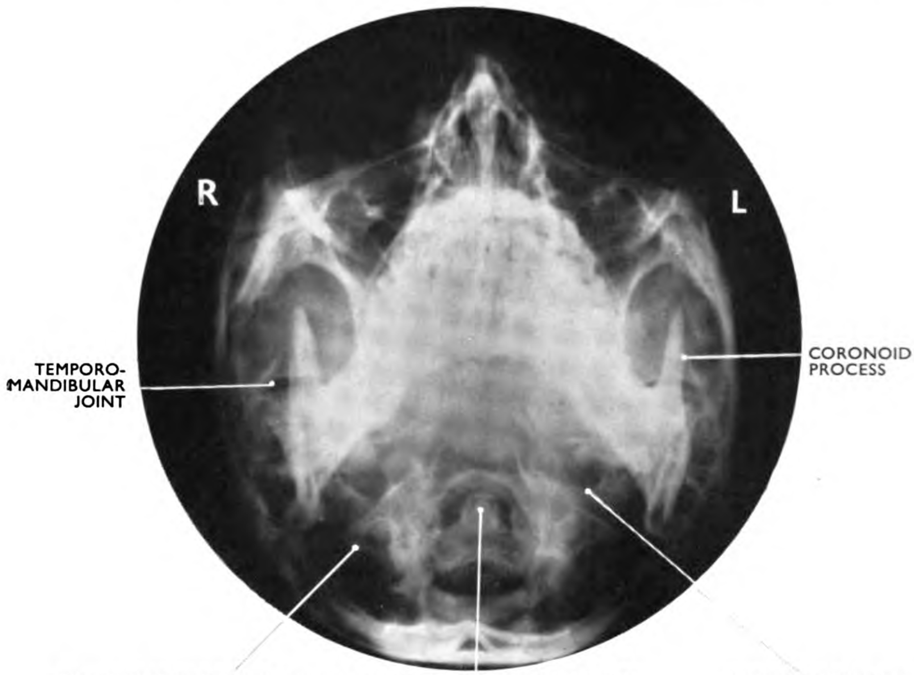


FIG. 213
Cranial bones : modified submento-vertical radiograph for jugular foramen.

tube tilted 20° toward the neck and centred on a line between the external auditory meatuses (intermeatal line). The shadows of the petrous temporal and transverse process of the atlas are now separated and the foramen is seen end on. The sigmoid sinus passes through the postero-lateral part of the foramen to become the internal jugular vein, and due to the fact that the superior sagittal sinus usually drains into the right transverse sinus, the right foramen is usually larger than the left ; however, in this subject, the left foramen is larger than the right. Note also in this radiograph that the coronoid process of the mandible, the transverse process of the atlas and the odontoid process of the axis are well demonstrated.

RADIOGRAPHIC APPEARANCES OF THE TEMPORAL BONE

Owing to the position and complexity of the temporal bone, no one radiographic view will demonstrate all the anatomical features. For the purposes of detailed examination the temporal bone is divided into petrous and mastoid parts; at least two radiographic views are taken of each part from different aspects, and each view is designed to demonstrate particular features free from obscuring shadows.

Various radiographic views have been described, but only those in common use will be given in this short account.

Mastoid Part of Temporal Bone

1. Postero-anterior oblique radiograph (profile view of mastoid process).
2. Lateral oblique radiograph (Law's projection).
3. 30° fronto-occipital radiograph (Towne's projection).

Petrous Part of Temporal Bone

1. Oblique postero-anterior radiograph.
2. 30° fronto-occipital radiograph (Towne's projection).

Additional view:

3. Submento-vertical radiograph.

Mastoid Part of Temporal Bone

1. Postero-anterior Oblique Radiograph (Profile View of Mastoid Process) (Fig. 214)

This radiograph is taken with the head turned away from the side under examination, so that the mastoid process is seen in profile at the side of the cranium; the chin is depressed to prevent superimposition of the shadow of the squamous part of the occipital bone on the mastoid area. The radiograph may be taken as an antero-posterior or a postero-anterior projection, and it shows the extent and type of air cells in the mastoid process and the thickness of the cortical bone.

In this particular radiograph (Fig. 214), air cells extend throughout the mastoid process and into the squamous part of the temporal bone above the level of the petrous ridge; the cortical bone of the mastoid process is thin. A curved line of denser bone medial to the mastoid process is cast by the cerebral surface of the mastoid part and is continuous below with the floor of the posterior cranial fossa. The arcuate eminence on the superior border of the petrous part is clearly visible, and medial to it the superior semicircular canal can be identified as a small vertical curved line of decreased bone density which

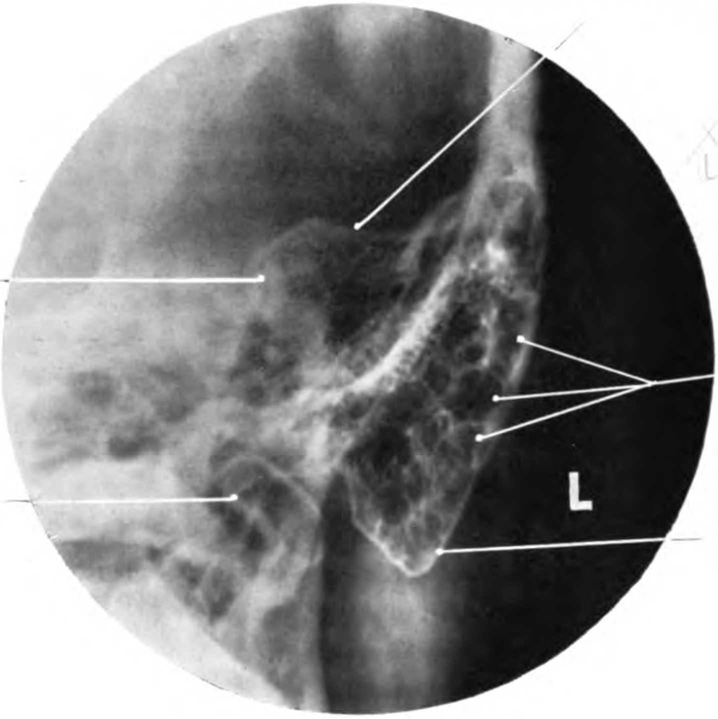


FIG. 214
Mastoid part of temporal bone : postero-anterior oblique radiograph.

opens below into the rounded shadow of the vestibule. An oblong outline of denser bone medial to the tip of the mastoid process is cast by the head of the mandible.

2. **Lateral Oblique Radiograph (Law's Projection)** (Fig. 215)

For this radiograph the head is placed with the median plane parallel to the film ; the X-ray tube is angled 15° forward and 15° downward and is centred on the mastoid process of the side nearest the film. This radiographic view is roughly at a right angle to the profile view of the mastoid process and provides a good demonstration of the mastoid air cells, not only in the mastoid process but also cells which may be present above and behind the process.

From the bottom of the radiograph the shadow of the posterior border of the ramus of the mandible extends upward and slightly backward and is continuous with the outline of the head which is partly obscured by the denser shadow of the petrous part of the temporal bone. The petrous temporal is seen very obliquely; its well-defined upper surface inclines downward and is crossed, above the head of the mandible, by the fainter shadow of the zygomatic arch. Behind the head of the mandible and separated from it by a

thin plate of denser bone (the tympanic plate) is an ill-defined oval area of decreased bone density cast by the external auditory meatus. In this view the tegmen tympani or roof of the mastoid antrum lies in the upper surface of the petrous bone immediately above the shadow of the external auditory meatus. From the region of the antrum the bubble-like mastoid cells extend backward

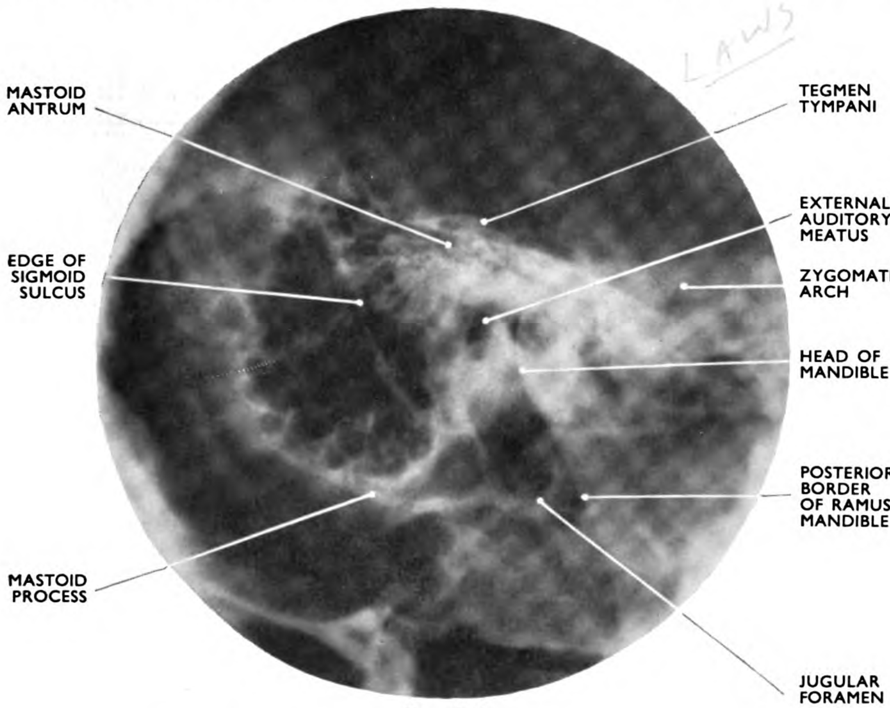


FIG. 215
Mastoid part of temporal bone : lateral oblique radiograph.

and downward throughout the mastoid process. In this particular radiograph the air cells also extend upward above the level of the petrous part into the squamous part of the temporal bone (squamous cells) and into the zygomatic process (zygomatic cells). The relationship of the cells to the sigmoid sinus is of importance to the surgeon; the shadow of the posterior margin of the sigmoid sulcus is seen crossing the mastoid process obliquely downward and forward. It is also possible on this radiographic view to identify the position of a large vein which is often found emerging from the bone behind the mastoid process. Note also that the jugular foramen is clearly visible below the head of the mandible.

3. **30° Fronto-occipital Radiograph (Towne's Projection)** (Fig. 208, p. 239)

In this view the mastoid air cells are seen almost end on inside the shadow of the side wall of the cranium. A direct comparison of the cells of both mastoid areas may be made on a single film, and this may be of great value

in the recognition of the early stage of infection when the loss of transradiancy of the affected side may be very slight. This view is also of value in the detection of cells in the petrous part of the temporal bone, for they may on occasion extend as far medially as the apex of the petrous bone.

Petrous Part of the Temporal Bone

1. **Oblique Postero-anterior Radiograph** (Fig. 216)

This radiographic projection provides a good view of the length of the petrous part of the temporal bone and demonstrates the bony labyrinth and the internal acoustic meatus. If the patient faces the film, rotation of the head through 45° will bring the long axis of the petrous bone of the side nearest the

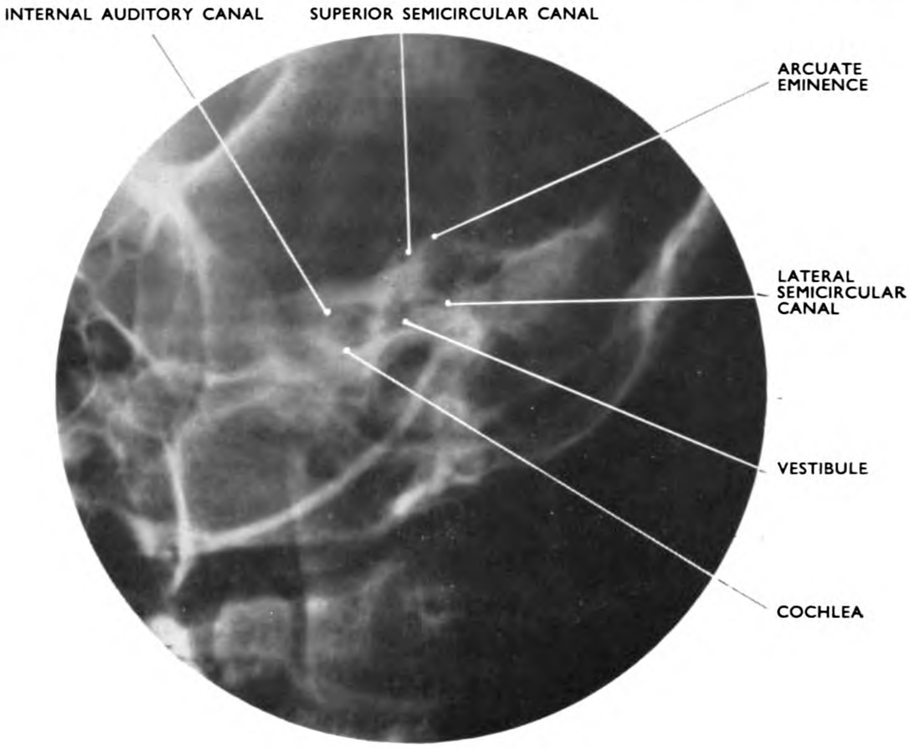


FIG. 216
Right temporal bone : oblique postero-anterior radiograph of petrous part for internal labyrinth.

film parallel to it; to avoid superimposition of the shadow of the squamous part of the occipital bone on to the area of the bony labyrinth, the X-ray tube is angled 12° upward and centred midway between the external occipital protuberance and the external auditory meatus.

The superior and lateral semicircular canals may be recognised as thin vertical and horizontal lines of decreased bone density radiating from the small round shadow of the vestibule. The prominence on the petrous ridge above

the superior semicircular canal is the arcuate eminence. Medial to the vestibule is the larger rounded shadow of the cochlea; the internal acoustic meatus lies parallel to the petrous ridge and appears to run into the cochlea, but is separated from it by a thin plate of bone perforated for the passage of the fibres of the acoustic nerve. Mastoid air cells are visible lateral to the semicircular canals and the thinness of the bone of the tegmen tympani can be appreciated. This view may also be of value in the detection of mastoid cells in the petrous part of the temporal bone medial to the bony labyrinth.

2. **30° Fronto-occipital Radiograph** (Fig. 208, p. 239)

3. **Submento-vertical Radiograph** (Fig. 211, p. 243)

These two views are complementary in that they demonstrate the petrous part of the temporal bone from two different aspects. The 30° fronto-occipital radiograph shows the petrous ridge, *i.e.*, the well-defined border between the superior and posterior surfaces. The submento-vertical radiograph shows the full length of the bone and in particular the posterior surface can only be seen in this view.

RADIOGRAPHIC APPEARANCES OF THE FACIAL BONES

The facial bones are usually examined as a group with the exception of the nasal bones, mandible and teeth which are radiographed separately. Two principal radiographic views are used, the occipito-mental and the lateral projection. In the occipito-frontal view of the skull (Fig. 207) it is evident that a large part of the facial bones is obscured by the superimposed shadows of the base of the skull; this superimposition may be overcome by tilting the head into the occipito-mental position, so that the petrous shadows fall below the maxillae. The lateral view requires no explanation except to note that the bones of both sides of the face are superimposed, although the bones of the side nearest the film are usually more sharply defined than those of the side farthest from the film.

Facial Bones: Occipito-mental Radiograph (Fig. 217)

The patient is positioned with the nose and chin toward the film, so that the base line is at 45° to the film; the X-ray tube is centred to the level of the lower margins of the orbits. The tilting of the head and the high centring of the tube results in projection of the shadows of the petrous part of the temporal bones below the maxillae.

In the radiograph the margins of the orbits are fully displayed. The frontal bone forms the supra-orbital margin and also the upper part of the lateral margin. The frontal sinuses are visible as leaf-shaped transradiant areas in the frontal bone; the two sinuses are separated above the root of the nose by a bony septum. The upper part of the nasal cavity and the anterior ethmoidal sinuses lie between the medial walls of the orbits but are obscured in this

radiographic view by the shadows of the nasal bones and nasal septum; the posterior ethmoidal and sphenoidal sinuses are superimposed on the lower part of the nasal cavity but their outlines cannot be clearly identified. The body of the maxilla contains the maxillary sinus whose outline is well shown. The upper (orbital) surface of the maxilla forms the medial part of the infra-orbital margin and the medial surface forms the greater part of the lateral wall of the nasal cavity. The alveolar process is not clearly seen as it is oblique

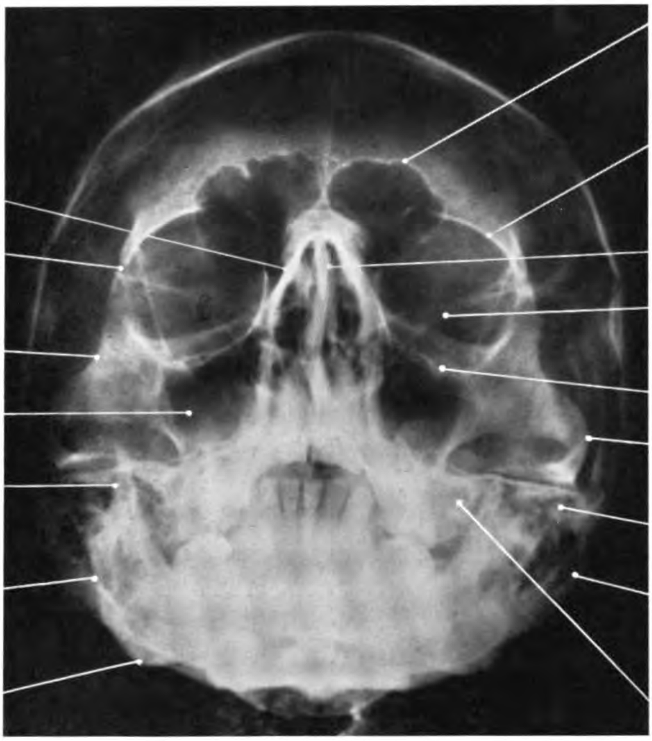


FIG. 217
Facial bones : occipito-mental radiograph.

to the X rays and its posterior part is overshadowed by the petrous bone. The star-shaped zygomatic bone lies on the lateral side of the maxilla; it forms the outer part of the infra-orbital margin and articulates above with the frontal bone at the fronto-zygomatic suture to complete the lateral margin of the orbit. The zygomatic arch is considerably foreshortened in this view. Below its posterior end lies the head of the mandible which is partly obscured by the superimposed shadow of the mastoid air cells; medial to it the sharp upward projection of the coronoid process is visible. The body of the mandible is completely overshadowed by the occipital bone. Note in this radiographic view that the lesser wing of the sphenoid is visible as two converging lines of denser bone extending across the orbit in an outward and slightly upward direction.

Figure 218 is a diagrammatic representation of the main features of this radiograph; note particularly the position of the petrous temporal bones in relation to the maxillae in the occipito-mental position.

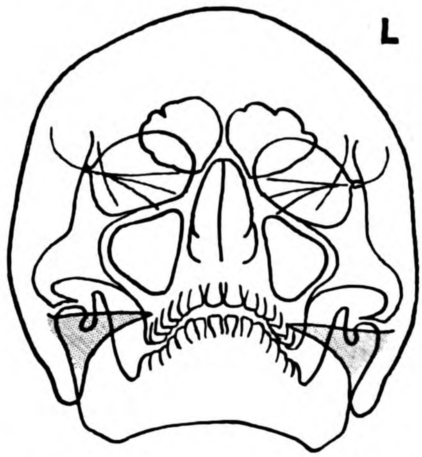


FIG. 218
Diagram of the occipito-mental radiograph of the facial bones.

Facial Bones: 30° Occipito-mental Radiograph (Fig. 219)

This radiographic projection provides a slightly different view of the facial bones from that seen in Figure 217. The head is positioned as for the occipito-mental radiograph, but the X-ray tube is angled downward at 30° and centred on the upper lip. This view demonstrates the zygomatic bone and the adjacent

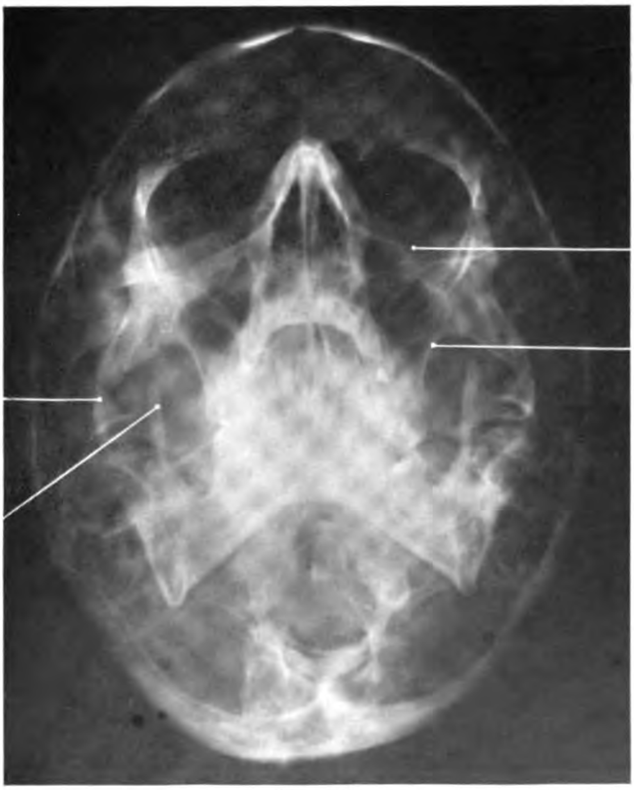


FIG. 219
Facial bones: 30° occipito-mental radiograph.

part of the maxilla ; the zygomatic arch is clearly seen although it is moderately foreshortened. Note also that the coronoid process of the mandible is well displayed.

Facial Bones: Lateral Radiograph (Fig. 220)

Positioning of the head is similar to that for the lateral radiograph of the cranial bones, *i.e.*, the median plane of the head is parallel and the interorbital

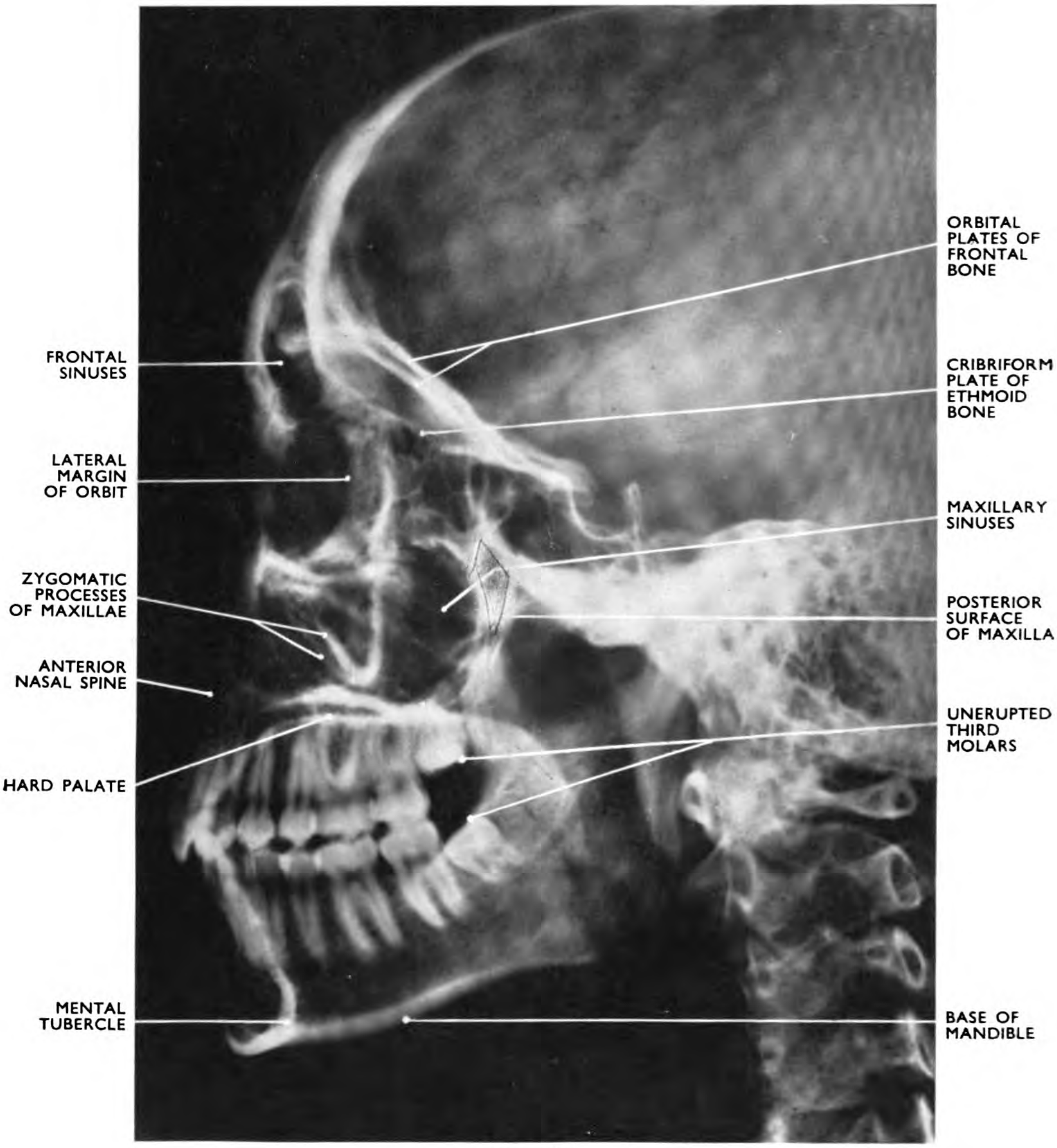


FIG. 220
Facial bones : lateral radiograph.

line at right angles to the film; the X-ray tube is, however, centred to the zygomatic bones.

The frontal sinuses are clearly visible between the inner and outer tables of the frontal bone above the bridge of the nose. Two parallel curved lines of denser bone extend backward from the region of the frontal sinuses to the anterior clinoid processes and are cast by the orbital plates of the frontal bone. A single less dense line of bone below these two lines is due to the cribriform plate of the ethmoid in front and the upper surface of the body of the sphenoid behind. The infra-orbital margin is visible as a short curved line of dense bone, convex downward; extending upward from it with a concave anterior border is the shadow of the lateral orbital margin. The anterior margins of the roof, floor and lateral wall of the orbital cavity are therefore visible on this lateral radiograph; posteriorly the orbit narrows to an apex which is situated near the base of the anterior clinoid process, but only the orbital roof is clearly visible in this area. Superimposed on the middle one-third of the orbit behind the lateral orbital margin is a series of confused lines cast by the walls of the ethmoidal sinuses and the roof of the nasal cavity. The transradiant sphenoidal sinuses occupy the body of the sphenoid but the anterior wall of the sinuses cannot be distinguished from a curved line of denser bone cast by the floor and anterior wall of the middle cranial fossa. The hard palate is clearly visible and is formed in front by the palatine processes of the maxillae and behind by the horizontal plates of the palatine bones. It forms the floor of the nasal cavity and the roof of the mouth. The alveolar processes of the maxillae project downward below the level of the hard palate and contain the sockets of the upper teeth. The roof of the maxillary sinus is formed by the upper (orbital) surface of the maxilla and the floor by the palatine and alveolar processes; the posterior margin of each sinus is formed by the posterior wall of the maxilla and is visible as a thin curved line of denser bone, concave forward, situated above the last upper molar tooth which in this subject is unerupted. The zygomatic process of the maxilla casts a dense V-shaped shadow on the maxillary sinus below the infra-orbital margin. The main features of the mandible are demonstrated although the coronoid process is partly overshadowed by the posterior part of the maxilla and the head of the mandible is almost obscured by the dense shadow of the petrous part of the temporal bone.

RADIOGRAPHIC APPEARANCES OF THE PARANASAL SINUSES

Owing to the differing positions of the various sinuses no one radiographic view will demonstrate them all satisfactorily. A number of radiographic views are taken; each one is designed to demonstrate a particular sinus, but may also show another sinus from a different aspect.

Six radiographic views are commonly employed :—

1. Occipito-mental radiograph for the Maxillary and Frontal Sinuses.
2. Occipito-frontal radiograph for the Maxillary, Ethmoidal and Sphenoidal Sinuses.
3. 10° Occipito-frontal radiograph for the Frontal, and Anterior Ethmoidal Sinuses.
4. Lateral radiograph for the Frontal and Sphenoidal Sinuses.
5. Submento-vertical radiograph for the Posterior Ethmoidal and Sphenoidal Sinuses.
6. Oblique radiographs for the Posterior Ethmoidal Sinuses.

1. **Occipito-mental Radiograph: Maxillary and Frontal Sinuses** (Fig. 221)

This radiographic view is that employed in the examination of the facial bones. With the patient facing the film the head is adjusted so that the base

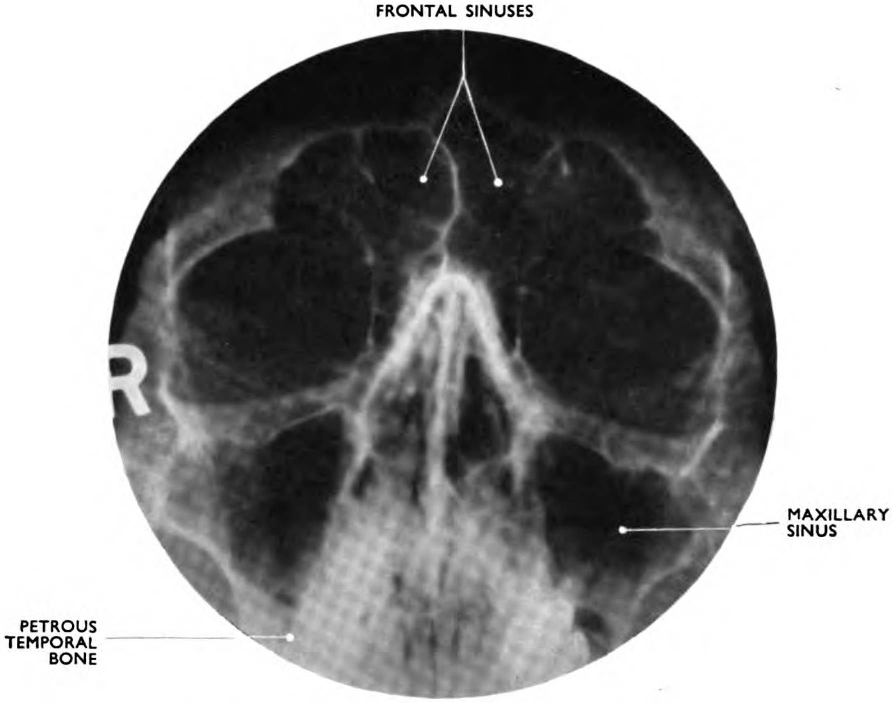


FIG. 221
Maxillary and frontal sinuses : occipito-mental radiograph.

line is at 45° to the film ; this position results in projection of the dense petrous shadows below the lower part of the maxillary sinuses. Note that the maxillary sinus occupies the whole of the body of the maxilla ; in this view it is roughly pyramidal in shape, with the base formed by the lateral wall of the nasal cavity and the apex situated in the zygomatic process of the maxilla. The roof is formed by the orbital surface of the maxilla and the lateral wall by the anterior or facial surface. There is also a short horizontal floor situated between the

base and the lateral wall and this is formed by the alveolar process of the maxilla; at this site the roots of the second premolar and molar teeth lie in very close proximity to the sinus which may therefore be infected by disease of the tooth roots or may be damaged during teeth extraction.

The frontal sinuses are separated by a bony septum, which is often deviated to one side; there may also be incomplete bony septa in each sinus. The vertical extent of the frontal sinuses can be seen on this radiograph, but a possible posterior extension into the orbital plate of the frontal bone can only be assessed on the lateral radiograph. A small part of the anterior ethmoidal sinus is visible between the medial wall of the orbit and the shadow of the nasal bones, but this view does not afford an adequate demonstration. Owing to the tilt of the head, the shadows of the posterior ethmoidal and sphenoidal sinuses are projected on to the nasal cavity, but detail of their structure is obscured by the nasal septum and conchae.

2. **Occipito-frontal Radiograph: Maxillary, Ethmoidal and Sphenoidal Sinuses** (Fig. 222)

This radiograph is taken with the patient facing the film and with the base line at 90° to the film; the petrous shadows are projected on to the orbits.

The bony outlines of the maxillary sinuses are clearly visible, although superimposed upon them are the lateral masses of the atlas vertebra. In the

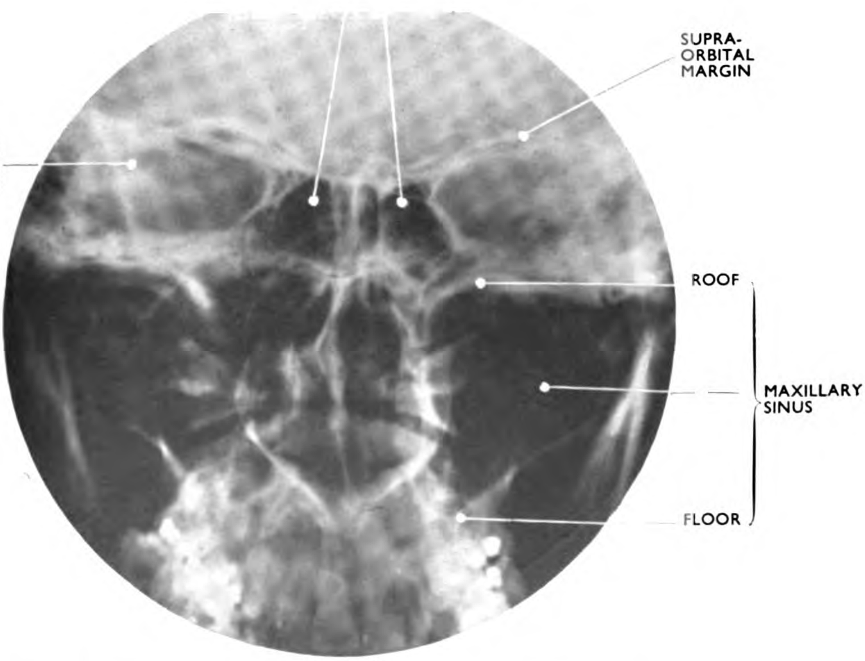


FIG. 222
Maxillary, ethmoidal and sphenoidal sinuses: occipito-frontal radiograph.

occipito-mental radiograph the floor of the sinus, situated over the alveolar process of the maxilla, was seen obliquely owing to the tilt of the head; a truer perspective is seen in this radiograph as the X rays are now directed parallel to the floor of the sinus. Between the orbits is a transradiant area due to the air-filled ethmoidal and sphenoidal sinuses, separated in the midline by the nasal septum and the upper part of the nasal cavity. In this projection the ethmoidal and sphenoidal sinuses are superimposed, so that if there is a loss of transradiancy on one side, it is impossible to determine exactly which sinus is abnormal; further radiographic views may then have to be taken to demonstrate the ethmoidal and sphenoidal sinuses separately. The bony outline of the frontal sinuses may be faintly seen above the supra-orbital margins.

This occipito-frontal radiograph provides a good view of the maxillary sinuses at a different angle from that seen in the occipito-mental radiograph; the ethmoidal and sphenoidal sinuses are superimposed; the frontal sinuses are not clearly demonstrated as their shadow is foreshortened.

3. 10° Occipito-frontal Radiograph: Frontal and Anterior Ethmoidal Sinuses (Fig. 223)

For this radiograph the patient's head is positioned as for the occipito-frontal radiograph; the X-ray tube is then angled 10° downward to centre on

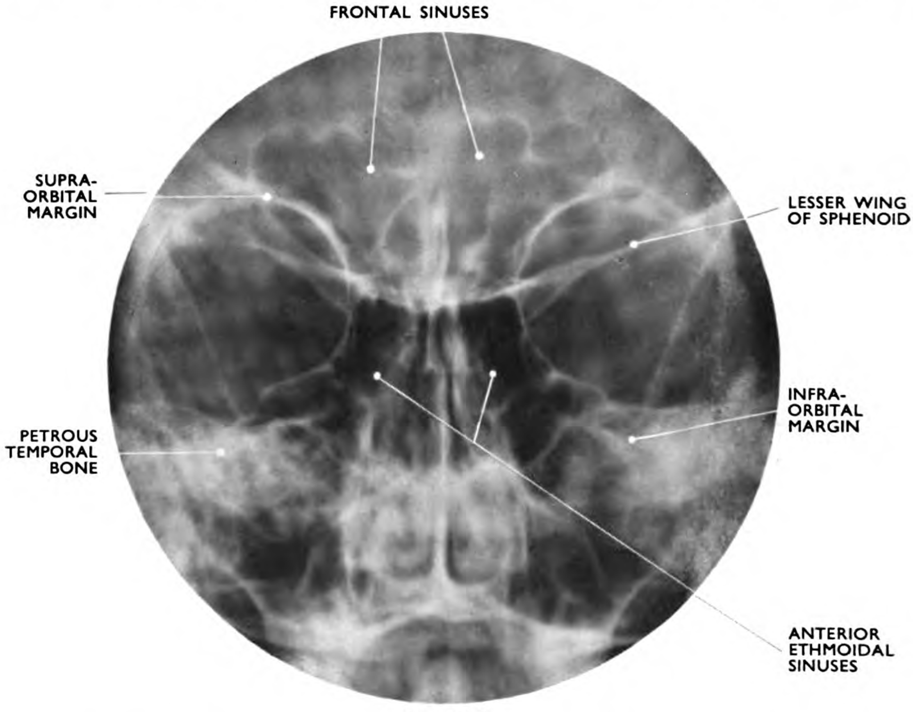


FIG. 223
Frontal and anterior ethmoidal sinuses: 10° occipito-frontal radiograph.

the root of the nose. In this view the petrous shadows are projected on to the upper parts of the maxillary sinuses. The frontal sinuses are clearly shown with very little distortion. Owing to the downward angulation of the tube, only the anterior ethmoidal sinuses are now seen between the medial borders of the orbits; the posterior ethmoidal and sphenoidal sinuses are projected to a lower level and are obscured by the base of the cranium and the nasal conchae.

4. **Lateral Radiograph: Frontal and Sphenoidal Sinuses** (Fig. 224)

In this lateral radiograph the paired sinuses are superimposed on each other. The frontal sinuses are seen as a transradiant area in the frontal bone above the root of the nose. The vertical extent of these sinuses is clearly shown, but only on this lateral view can a posterior extension of the sinuses into the

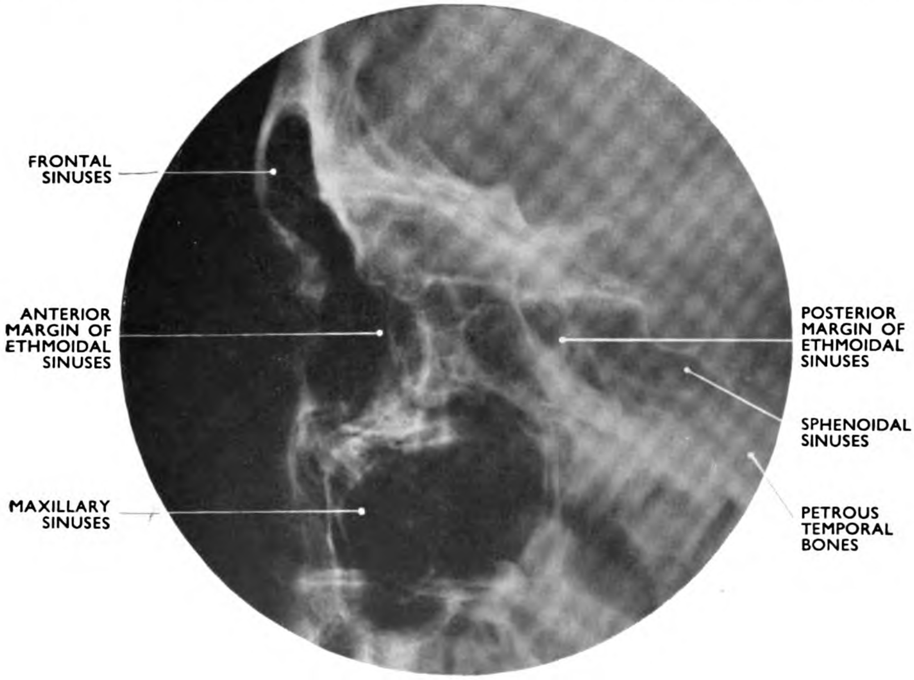


FIG. 224
All sinuses superimposed : lateral radiograph.

orbital plates of the frontal bone be demonstrated; in this particular radiograph, no posterior extension is present. The thickness of the anterior wall of each sinus may vary; if it is much thicker on one side than the other, then that sinus may appear less transradiant in the 10° occipito-frontal radiograph, and without the lateral radiograph could be diagnosed as abnormal. The sphenoidal sinuses occupy the body of the sphenoid and are well developed in this patient; their extent can be roughly estimated, but it is often difficult

to determine the exact sinus outlines, especially anteriorly where they are adjacent to the posterior ethmoidal sinuses. Note the relation of the sphenoidal sinuses to the sella turcica and the thinness of the bone which separates the sinuses from the pituitary fossa; infection of the sinuses may spread to the brain, meninges or blood-vessels in the region of the sella, and conversely tumours in that region may invade the sinuses. The outlines of the maxillary sinuses are visible; the posterior wall of each sinus casts a well-defined line of dense bone which extends upward from the shadow of the posterior end of the hard palate. Note also that the floor of the maxillary sinus extends below the level of the hard palate into the alveolar process of the maxilla and lies in very close proximity to the roots of the molar teeth.

Submento-vertical Radiograph: Posterior Ethmoidal and Sphenoidal Sinuses (Fig. 225)

On this radiographic view of the base of the cranium, each sphenoidal sinus is separately visible as a well-defined transradiant area. The two sinuses are often asymmetrical with deviation of the septum to one side, as in this radiograph. The posterior ethmoidal sinuses are seen on either side of the nasal septum between the shadow of the posterior surface of the body of the mandible and the sphenoidal sinuses.

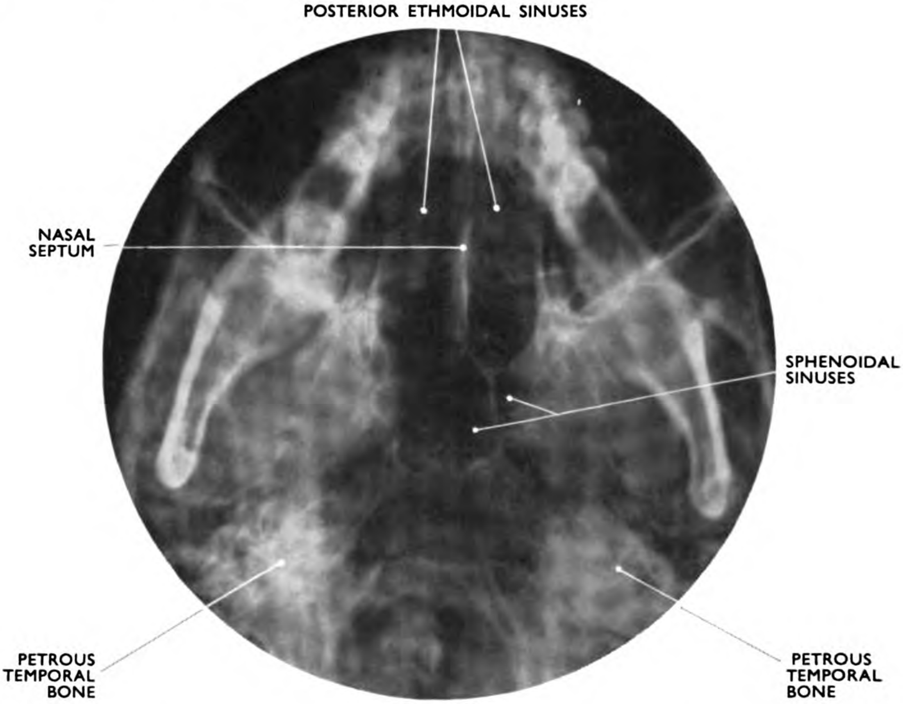


FIG. 225

Posterior ethmoidal and sphenoidal sinuses : submento-vertical radiograph.

Oblique Radiographs: Posterior Ethmoidal Sinuses and Optic Foramina (Fig. 226)

For this radiograph the patient faces the film, the head is then rotated 40° and the chin raised so that the base line is at 30° to the horizontal. In the right oblique radiograph the right posterior ethmoidal sinuses are seen in

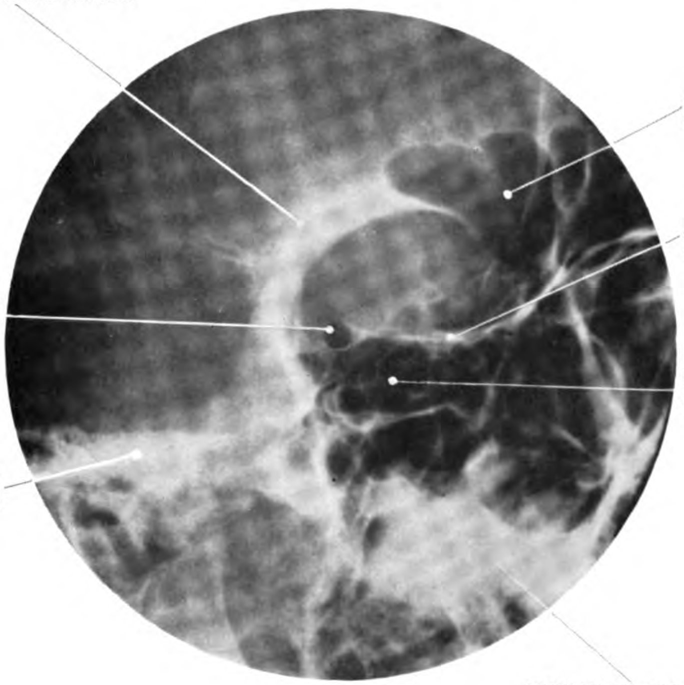


FIG. 226
Posterior ethmoidal sinuses and optic foramen : right oblique radiograph.

the right orbit, clear of superimposed shadows. This projection also demonstrates the right optic foramen, which is seen end-on as a rounded transradiancy; it is seen at the posterior end of a curved line of dense bone cast by the upper part of the body and the lesser wing of the sphenoid of the opposite side.

In a series of simplified diagrams, Figures 227, A to F (p. 262), the relative positions of the sinuses in the different radiographic views should be noted.

RADIOGRAPHIC APPEARANCES OF THE MANDIBLE AND TEMPORO-MANDIBULAR JOINT

Due to the curved shape of the mandible, this bone cannot be satisfactorily demonstrated on a single film. Three principal radiographic views are commonly taken to demonstrate :—

1. The ramus and posterior part of the body.
2. The anterior part of the body.
3. The head and the temporo-mandibular joint.

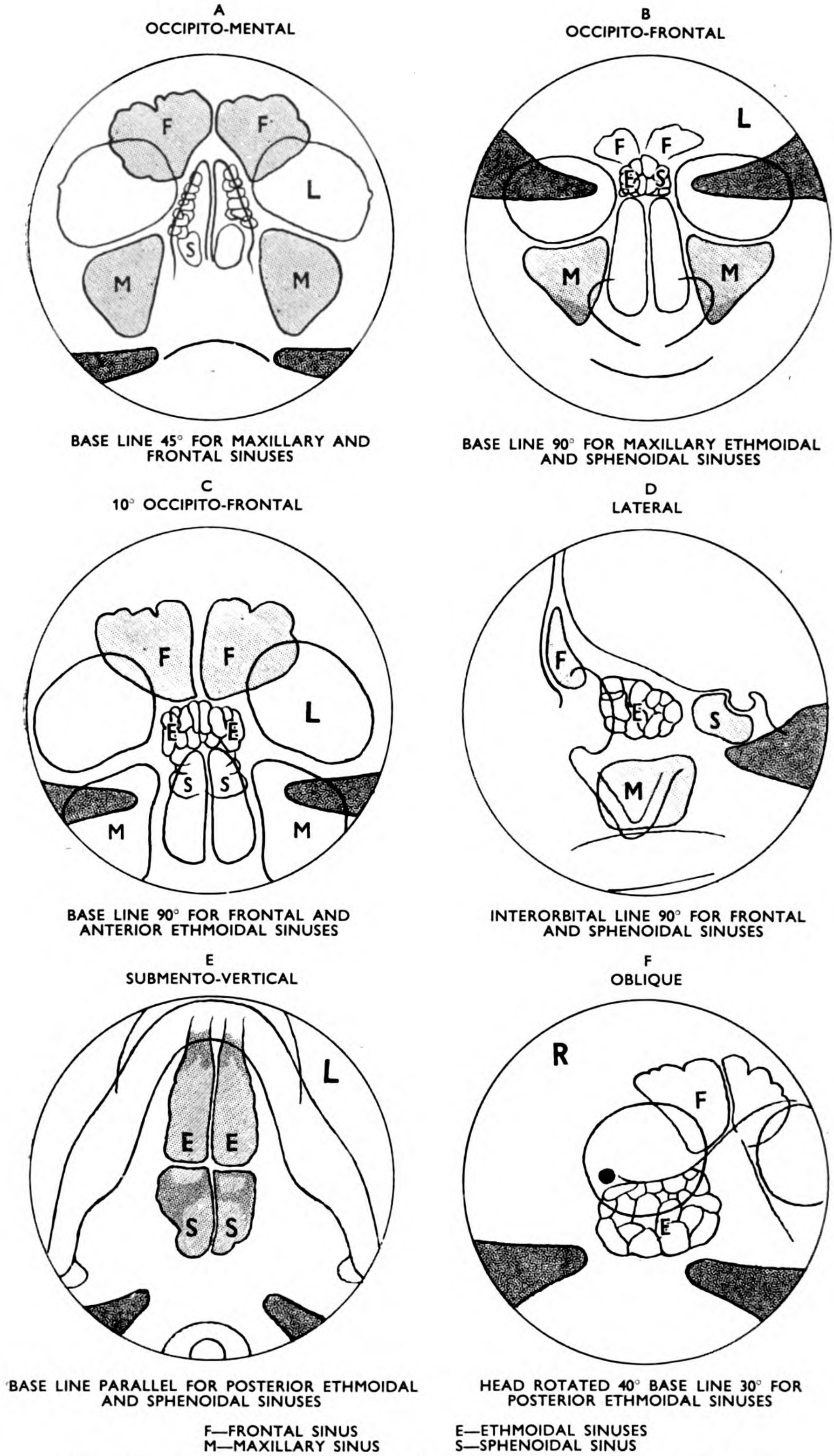


FIG. 227—A to F, diagrams of the radiographic views of the paranasal sinuses.

Mandible: Right Lateral Oblique Radiograph (Fig. 228)

This radiographic view demonstrates the ramus and the posterior part of the body of the mandible. The patient's head is turned to place the ramus and posterior part of the body in contact with the film; the X-ray tube is then directed upward so that the shadow of the opposite side of the mandible is projected above the side under examination.

In the radiograph the body of the mandible is visible as far forward as the

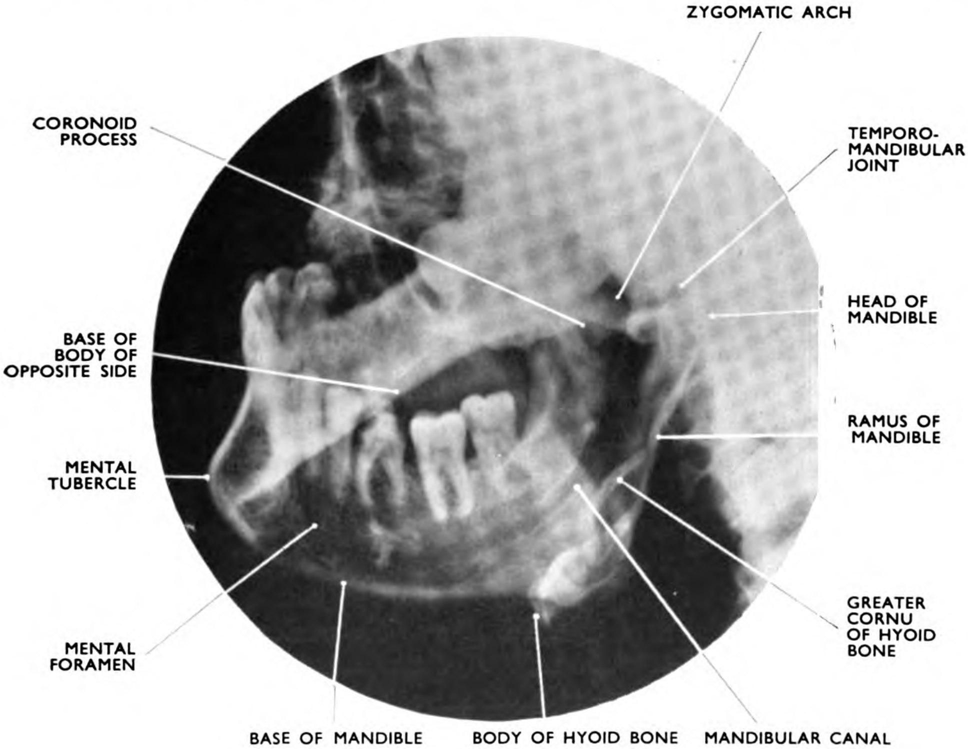


FIG. 228
Mandible : right lateral oblique radiograph.

root of the second premolar tooth; the ramus is well shown, although the tip of the coronoid process is obscured by the zygomatic arch and the head of the mandible by the dense shadow of the petrous temporal bone. Note that the angulation of the tube causes superimposition of the shadow of the hyoid bone on to the angle of the mandible, and that the shadow of the air-filled pharynx is superimposed on the ramus. The mandibular canal is visible as a channel of decreased bone density extending downward from the middle of the ramus into the base of the body and ending at the mental foramen below the root of the second premolar tooth. Owing to the presence of this foramen and the deep root sockets of the premolar teeth, fractures often take place

at this site. The posterior end of the mylohyoid line is seen as a line of denser bone crossing the roots of the second and third molar teeth in a downward and forward direction; this line ends near the lower border of the symphysis menti and divides the internal surface of the body into the sublingual fossa above and the submandibular fossa below, but the anterior part of the line is not radiographically visible.

Mandible: Postero-anterior Radiograph (Fig. 207)

This postero-anterior view of the mandible is similar to that seen in the occipito-frontal radiograph of the skull (Fig. 207); the posterior part of the body and the ramus are now seen in profile, and the anterior part of the body is roughly parallel to the film, although it is partly obscured by the superimposed shadow of the cervical spine. Note that the mandibular canal is visible in the ramus and that the shadow of the coronoid process is superimposed on the internal surface of the ramus. The head and neck of the condylar process are seen through the superimposed shadow of the zygomatic bone, but the temporo-mandibular joint cannot be clearly identified, owing to the dense petrous shadow. Also note that the head of the mandible is widened from side to side, and compare this postero-anterior view of the head with the lateral view (Fig. 229).

Mandible: Temporo-mandibular Joints, Lateral Radiograph (Figs. 229A and 229B)

In taking a lateral radiograph of the temporo-mandibular joint, some method is necessary to obtain a view clear of the joint of the opposite side and the shadows of denser parts of the base of the cranium; in this particular pair of radiographs, tube tilt toward the feet has been employed. The patient's head is placed in the true lateral position with the interorbital line at right angles to the film; the tube is angled 25° to the feet and centred on the temporo-mandibular joint under examination. A small cone is used to cover only the area required and it is usual to take two radiographs of the joint, one with the mouth closed (Fig. 229A) and the second with the mouth well opened (Fig. 229B) to study movements at the joint. On the radiograph note the configuration of the head of the mandible; it is narrow from before backward and is inclined slightly forward from the posterior border of the ramus. When the mouth is closed the head lies in the mandibular fossa of the temporal bone; the joint space appears wide, but it will be remembered that an articular disc is interposed between the articular surfaces. On opening the mouth, the head rotates and moves forward on to the articular tubercle, the articular disc following the movement of the head. This radiographic view of the joint is not only of value in the demonstration of dislocation, but also in the detection of fractures of the neck of the mandible.

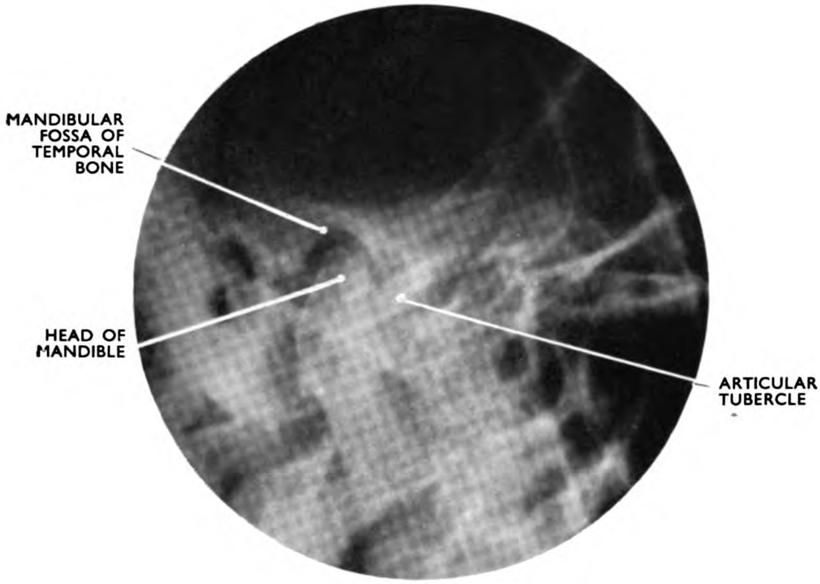


FIG. 229A
Left temporo-mandibular joint : lateral radiograph with mouth closed.

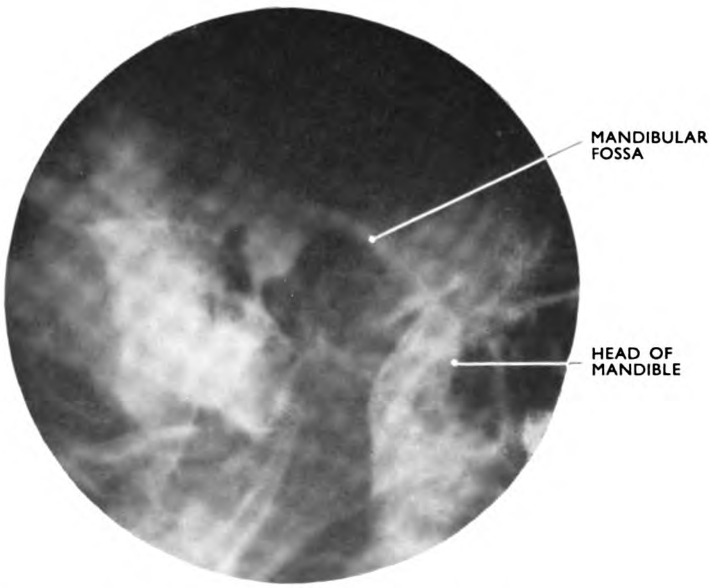


FIG. 229B
Left temporo-mandibular joint : lateral radiograph with mouth open.

Ossification and Bony Development of the Skull

Ossification of the bones of the vault of the cranium and the face takes place in membrane, but the bones of the base of the cranium ossify in cartilage; some bones, which form a part of the vault and the base, are therefore ossified partly in membrane and partly in cartilage from separate centres. Ossification of the bones of the skull is incomplete at birth, and some bones, such as the mandible, consist of separate pieces which do not fuse until after birth. A

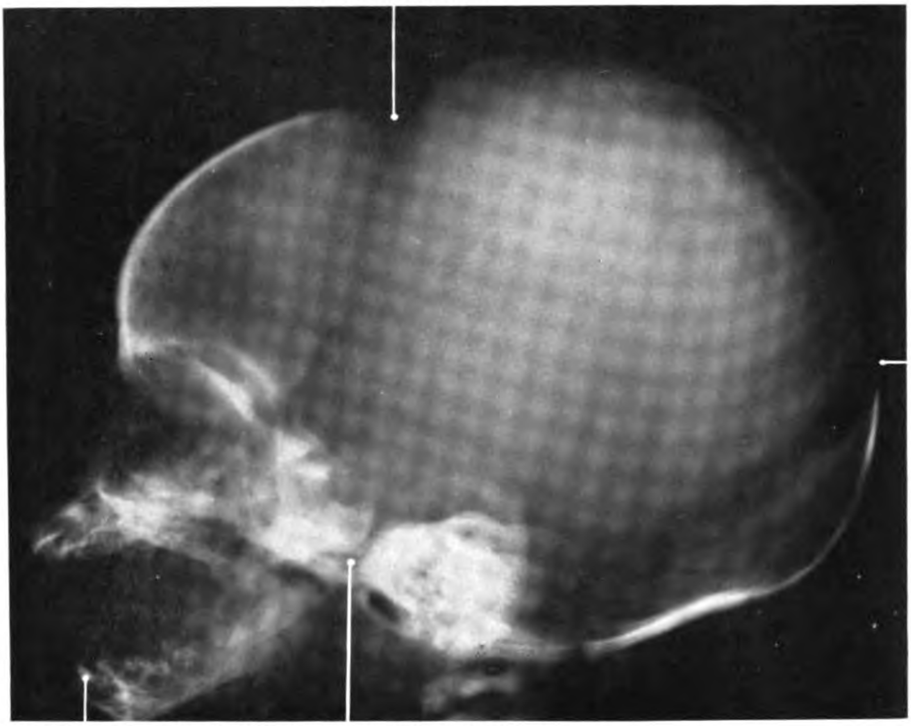


FIG. 230
The skull at birth : lateral radiograph.

common developmental variation is a failure of fusion of the two halves of the frontal bone which remain separated in the midline by a suture (the metopic suture) long after the normal age of fusion at the fifth year. Another common variant is the presence of Wormian bones; these small separate bones are found in the sutures of the vault of the skull of adults and arise from accessory centres of ossification. Attention has already been drawn to the presence of gaps, called fontanelles, in the vault of the skull of infants (Fig. 230). The anterior and posterior fontanelles, situated at the ends of the sagittal suture, are the largest of these fontanelles; the posterior fontanelle closes soon after birth by growth of the surrounding bone, but the anterior fontanelle

remains open until the second year. At birth the skull (Fig. 3), as a whole, is large as compared with the rest of the skeleton. The facial region of the skull is however relatively small as compared with the cranium, and this is mainly due to the small size of the upper and lower jaws; the deciduous teeth are developing in their crypts but are unerupted. The mastoid processes have not yet begun to develop and the paranasal sinuses are relatively very small. Growth of the skull is rapid up to the seventh year, when the petrous part of the temporal bones, the orbits and the foramen magnum have almost reached their full adult size. Between the seventh year and puberty, growth is slower, but after puberty there is a further period of rapid growth, coincident with the eruption of the permanent dentition and the great increase in the size of the sinuses. The sutures may begin to be obliterated after the thirtieth year, but in many cases they remain unfused in old age.

TEETH

The teeth consist of two dentitions, the deciduous and the permanent. The deciduous teeth erupt during the first two years of childhood and the permanent teeth replace them as the jaws grow to full maturity: this covers the period from the sixth year to some time between the seventeenth to the twenty-fifth year.

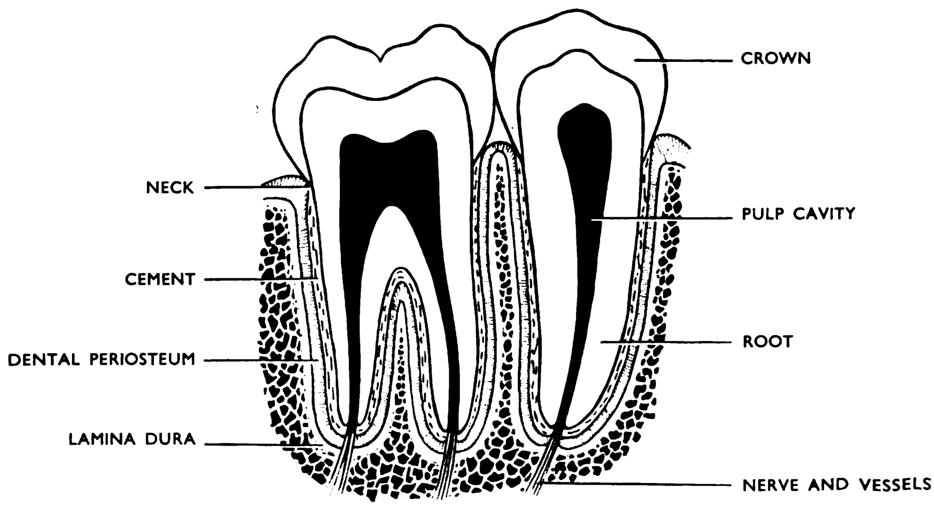


FIG. 231
Sectional diagram of teeth in their sockets.

Each tooth consists of three main parts, the crown, the neck and the root (Fig. 231). Enclosed down the centre of each is a canal known as the pulp cavity containing the blood-vessels and nerve of the tooth which enter the cavity through the apex of the root.

The main structure of the tooth is of a hard substance called dentine;

this is covered at the crown by an even denser layer of enamel. The enamel encases the tooth as far as the neck, where it is superseded by the cement covering of the root.

The socket for the tooth, contained in the alveolar process of the jaw, is lined with a compact layer of bone called the lamina dura; the fibrous periodontal membrane (dental periosteum) forms the attachment between the lamina dura and the tooth root, which is a peg-and-socket joint of the fibrous type.

Deciduous or Milk Teeth

This set consists of twenty teeth, ten in the upper arch and ten in the lower.

In each jaw the two **central incisors** occupy the medial positions in the dental arches at the front of the mouth, with a **lateral incisor** on either side of them. These teeth have single roots and crowns with bevelled cutting edges.

Distal to the incisors are the **canine teeth,** two in each arch, with long single roots and crowns carrying single conical tubercles or cusps.

Beyond each canine, at the back of the dental arches, are two **molar teeth,** with roots having three prongs in the upper jaw and two prongs in the lower jaw. These roots are splayed in order to give space between them for development of the permanent premolar teeth which will eventually replace them.

The crowns of the molar teeth are somewhat square in shape, with bulging sides that overhang the necks: they carry on their grinding surfaces three to five cusps which interlock with their opposite numbers when the jaws are occluded.

Permanent Teeth

The permanent set consists of thirty-two teeth, sixteen in each jaw.

The **incisors,** medial and lateral, and the **canines** are similar to those of the deciduous dentition although they are larger in size.

In addition there are eight **premolar** (bicuspids), two distal to each canine tooth, occupying the position previously filled by the deciduous molars. These teeth usually have single roots which are grooved; occasionally a root may be bifurcated down the line of the groove. The premolars have crowns with two cusps, one labial (cheek side) and the other lingual (toward the tongue).

Beyond each premolar, where previously there were no teeth in the deciduous dentition, are three permanent **molars.** The molar teeth of the upper jaw have three roots, one lingual and two labial or buccal; the roots of the smaller third molars are often partly fused and pyramidal in shape. The lower molars have two roots, one mesial, the other distal, curved with a slight backward inclination. The crowns display from three to five cusps and are larger than the molars of the upper jaw.

The teeth are referred to by means of dental formulae using letters of the alphabet to denote the deciduous teeth, and numerals for the permanent dentition :—

$$\begin{array}{r|l} \text{R}\quad \text{edcba} & \text{abcde}\quad \text{L} \\ \hline \text{edcba} & \text{abcde} \end{array}$$

and

$$\begin{array}{r|l} \text{R}\quad 87654321 & 12345678\quad \text{L} \\ \hline 87654321 & 12345678 \end{array}$$

The cross lines dividing the jaws into upper and lower sections of the right and left side, arranged for viewing with the subject in the anatomical position, *i.e.*, as seen from the buccal aspect.

Thus, should a hospital request form show |4, it indicates that the radiograph of the lower left first premolar is required, and 6| would denote that a film of the upper right first molar must be taken.

Development of the Teeth

The teeth begin to develop as early as the sixth week of intrauterine life and at birth calcification of the deciduous teeth is well advanced (Fig. 3). Beside the lingual aspect of each deciduous tooth lies the bud of the permanent tooth, which will eventually replace it, and, at this stage, tooth buds of the first permanent molars are also present beyond the area of the deciduous teeth.

Each tooth, deciduous or permanent, develops in its own erupting sac or crypt, until it is hard enough to bear the pressure which will be exerted on it during mastication. When this stage has been reached it erupts through the fibrous tissues of the gum and becomes visible. During this growing period of the permanent teeth the roots of the deciduous teeth are absorbed, leaving the crowns to be pushed off by the pressure of the developing tooth below.

The following tables give the probable dates of eruption of both dentitions, but there is considerable variation, and in some subjects the permanent third molars may never develop at all.

Eruption of Deciduous Teeth

Lower central incisors . . .	6 to 9 months
Upper four incisors	8 to 10 ,,
Lower lateral incisors . . .	15 to 21 ,,
First molars	15 to 21 ,,
Canines	16 to 20 ,,
Second molars	20 to 24 ,,

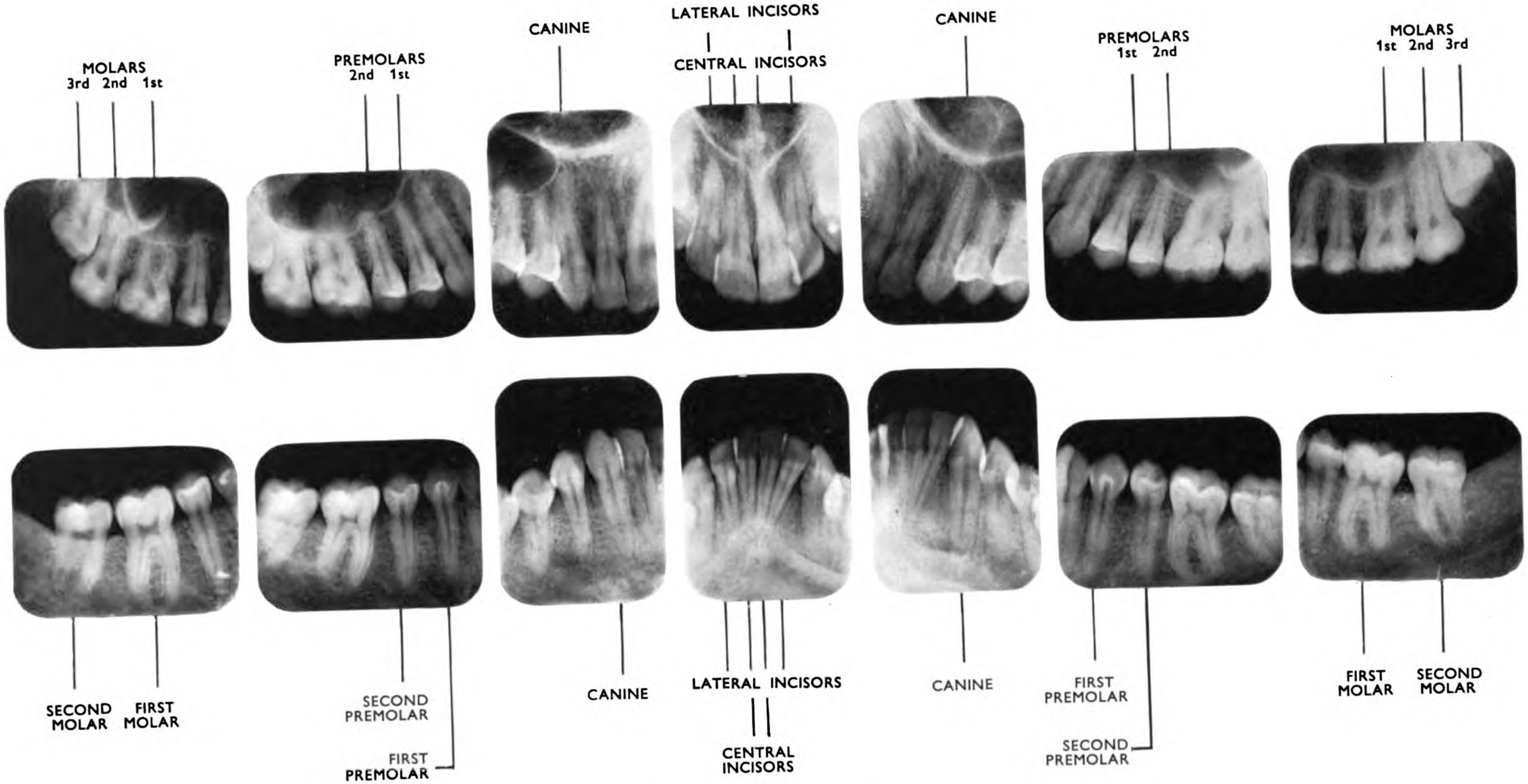


FIG. 232
Radiographs of a permanent dentition.

Eruption of Permanent Teeth

First molars	6th year
Central incisors	7th ,,
Lateral incisors	8th ,,
First premolars	9th ,,
Second premolars	10th ,,
Canines	11th to 12th year
Second molars	12th to 13th ,,
Third molars	17th to 25th ,,

It should be noted that the first permanent molars are in use before the loss of any deciduous teeth, giving the stability of a grinding surface during the change-over from one set of teeth to the other.

RADIOGRAPHIC APPEARANCES OF THE TEETH

Due to the curved shape of the jaws a number of small films are used to obtain radiographs of a full set of teeth; on any one film several teeth may be visible but usually only two or three are clearly seen with the least possible distortion or overlap. In Figure 232, seven films have been used for each jaw, covering the thirty teeth present; the lower third molars are absent in this subject.

Note the main radiographic features of a typical tooth in Figure 233.

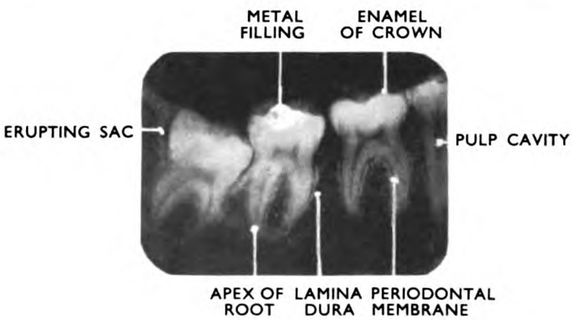


FIG. 233

The dentine which forms the main structure of a tooth casts a uniform shadow of greater density than the surrounding spongy bone of the jaw. The enamel of the crown is the densest substance in the body and forms a very strong protective cap over the exposed part of the tooth, whilst the pulp cavity in the centre and roots of the tooth is visible as a transradiant shadow. The lamina dura is the name given to the layer of compact bone of the socket wall; it casts a well defined shadow and is separated from the root of the tooth by a narrow transradiant space due to the periodontal membrane.

In Figure 232, it will be noticed that above the apices of the roots of the upper teeth transradiant shadows with well-defined lower margins are present. The transradiant shadow above the incisor and canine teeth is cast by the nasal cavity and above the premolar and molar teeth is the shadow of the maxillary sinus; these shadows overlap above the canine tooth. Beneath the apices of the roots of the incisors of the lower jaw the genial tubercles are visible as a small circular opacity, and below the roots of each second premolar tooth is a small transradiancy which is cast by the mental foramen. The mandibular canal may be seen below the roots of the molar teeth.

In the incisor and canine teeth a single root and central transradiant pulp cavity is visible. The canine tooth may be distinguished by its length and conical shaped crown. The premolars show two cusps, the labial one giving a longer shadow than the lingual since it is farther from the film. The four cusps on the square shaped crown of the molars are clearly visible; the third molars of the upper jaw are, as yet, unerupted. The details of the roots of the upper molars are partly obscured, but in the lower jaw the two roots of each molar tooth are distinctly visible; each root has its own pulp cavity and blood supply.

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Printed in Great Britain by THE DARIEN PRESS LTD., *Edinburgh*